DEPT. NAT. RES & ENV
PE907925

attachment to WCR
Core Analysis & Petrological Final Rpt
Iona-1
(W970)

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PETROLEUM DIVISION

SPECIAL CORE ANALYSIS and PETROLOGICAL FINAL REPORT

of

2 4 DEC 1998

IONA-1

for

WESTERN UNDERGROUND GAS STORAGE PTY LIMITED

by

ACS LABORATORIES PTY LTD

22 December, 1998

Western Underground Gas Storage Pty Limited
Level 4
459 Collins Street
MELBOURNE VIC 3000

Attention: Andy Whittle
Alan Tapley

FINAL REPORT: 0433-08

CLIENT REFERENCE:	Fax dated 17th November, 1998
MATERIAL:	1½" Core Plugs
LOCALITY:	Iona-1
WORK REQUIRED:	Special Core Analysis and Petrology

Please direct technical enquiries regarding this work to the signatories below under whose supervision the work was carried out.

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CONTENTS

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

This report details the procedures and presents the results of a Special Core Analysis study on a suite of samples from the Iona-1 well. The program was commissioned on 17th November 1998 by Western Underground Gas Storage Pty Limited.

A total of six 3½" core pieces were supplied for the study from which 1½" diameter plugs were drilled and stacked to create initially two, and eventually one, 5" long plug. A piece of cap rock was also provided for mercury injection seal analysis.

Chapter 2 summarises the entire program in the form of a test schedule and flow chart. The remaining chapters contain the procedures and results of the study. The Appendices contain ancillary information relevant to the study.

CHAPTER 2

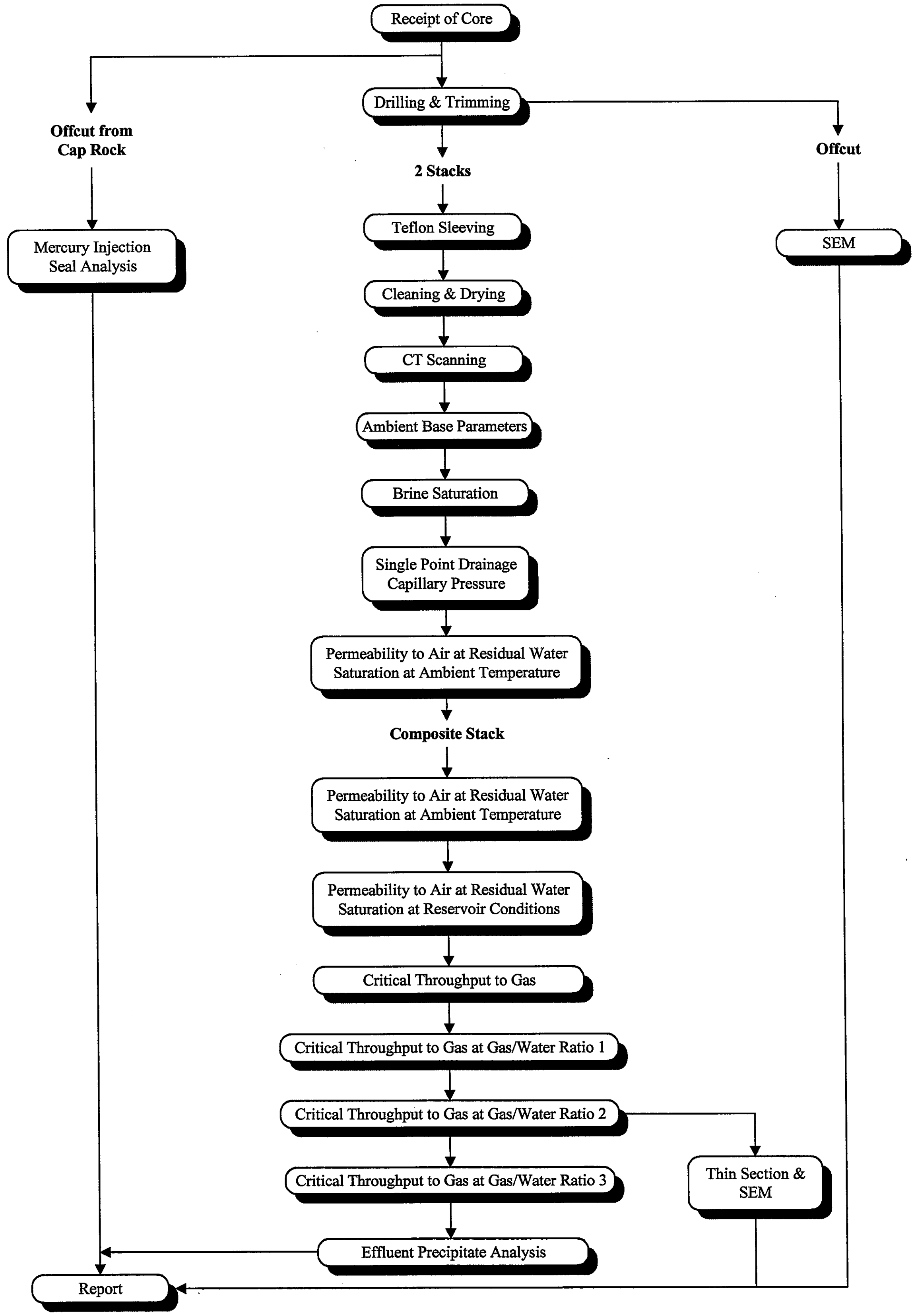
SUMMARY OF TEST PROGRAM

TEST SCHEDULE

Client Western Underground Gas Storage Pty Limited
Well Iona-1

Sample	Test Sequence																					
	Plug cutting with Liquid N_2	*Mount sample (2 stacks)*	*Cool solvent extraction*	*Humidity Dry*	*CT Scans*	*Ambient base parameters*	*Stack saturation*	*Single Point Pc to Swr*	*Keg @ Swr*	*Combine two stacks into one*	*Keg @ Swr*	*Kg @ Swr @ ResCon*	*Crtical Through-put to gas @ max. drawdown*	*Critical Through-put to gas & water - Ratio 1*	*Critical Through-put to gas & water - Ratio 2*	*Critical Through-put to gas & water - Ratio 3*	*Critical Through-put to gas, water and cond., single rate*	*Blow down samples trim end face for petrology*	*Hg injectin Seal analysis*	*SEM*	*Thin Section*	*Precipitate Analysis*
Stack 1	X	X	X	X	X	X	X	X	X	X												
Stack 2	X	X	X	X	X	X	X	X	X	X												
Combined Stack											X	X	X	X	X	X	X	X		X	X	X
Cap rock sample	X																		X			
Total	**10**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

FLOW CHART


Receipt of Core
Offcut from Cap Rock
Drilling & Trimming
Offcut
2 Stacks
Mercury Injection Seal Analysis
Teflon Sleeving
SEM
Cleaning & Drying
CT Scanning
Ambient Base Parameters
Brine Saturation
Single Point Drainage Capillary Pressure
Permeability to Air at Residual Water Saturation at Ambient Temperature
Composite Stack
Permeability to Air at Residual Water Saturation at Ambient Temperature
Permeability to Air at Residual Water Saturation at Reservoir Conditions
Critical Throughput to Gas
Critical Throughput to Gas at Gas/Water Ratio 1
Critical Throughput to Gas at Gas/Water Ratio 2
Thin Section & SEM
Critical Throughput to Gas at Gas/Water Ratio 3
Effluent Precipitate Analysis
Report

CHAPTER 3

SAMPLE PREPARATION AND BASE PARAMETER DETERMINATIONS

3.1 Test and Calculation Procedures

3. SAMPLE PREPARATION AND BASE PARAMETER DETERMINATIONS

3.1 Test and Calculation Procedures

3.1.1 Drilling and Trimming

The core pieces to be sampled were the 1/3 slab which had also been invaded by resin. Consequently the volume of core to be sampled was very limited, with a maximum plug length of ¾".

The highly friable core required plugging with liquid nitrogen to maintain the integrity of the plugs. Eight core plugs of 1½" diameter were drilled and trimmed to the maximum allowable lengths from the slabbed core sections provided.

3.1.2 Teflon Sleeving

As the plugs taken were short, two stacks each comprising four plugs were formed. Each stack was sleeved in teflon to prevent grain loss and maintain the integrity of the samples. Teflon sleeving consists of layers of PTFE tape wrapped around the samples and mesh screens situated at the end-faces held in place by shrinking an outer sleeve of heat sensitive teflon tubing around the samples.

3.1.3 Cleaning and Drying

As a precaution, the two stacks were soxhlet cleaned with a chloroform:methanol azeotrope. Cleaning was deemed complete when tests for hydrocarbons (fluorescence under UV light) and salt (silver nitrate precipitation) returned negative. The plugs were dried in a humidity oven at 60°C and 50% relative humidity. The dry samples were cooled to room temperature in a desiccator.

3.1.4 CT Scanning

CT Scanning was undertaken in order that internal inhomogeneities, resin and/or drilling fluid invasion zones may be noted. Typical inhomogeneities may be clasts, bedding sedimentary structures, cementation, fractures and any other discontinuities that may not be readily visible to the naked eye.

The principle of CT Scanning and its applications is presented by Hove et al, 1987 and Wellington and Vinegar, 1987.

CT Scanners generate cross-sectional image slices through the sample by revolving an X-ray tube around the sample and obtaining projections at many different angles (Appendix II). From these image slices, a cross-sectional image was reconstructed by a back projection algorithm in the scanner's computer.

Prior to analysis, arbitrary orientation lines were inscribed onto the sample using a marker to facilitate subsequent re-orientation. The sample was placed vertically within the scanner, with the orientation arrow left, and a longitudinal section image obtained. The sample was then rotated through exactly 90° to the initial orientation, and another section image recorded. These two images were labelled '0' and '90' on the prints.

The CT Scans of the two stacks were electronically mailed to Western Underground Gas Storage Pty Ltd representatives on 17th November, 1998. Digital images of the scans are shown in section 3.2.1 of this report.

3.1.5 Base Parameters

Porosity

Porosity was determined in two stages. Initially each sample was placed in a sealed matrix cup. Helium held at 100 psi reference pressure was then introduced to the cup. From the resultant pressure drop the unknown grain volume was determined from Boyle's Law.

$$P_1 V_1 = P_2 V_2$$
$$\Rightarrow P_1 Vr = P_2 (Vr + Vc + Vl - Vg)$$

where
P_1 = *initial pressure (psig)*
Vr = *reference cell volume (cm^3)*
Vc = *matrix cup volume (cm^3)*
Vl = *line volume (cm^3)*
Vg = *grain volume (cm^3)*
P_2 = *final pressure (psig)*

and
$$\rho = \frac{Wt}{Vg}$$

where
ρ = *grain density (g/cm^3)*
Wt = *weight of sample (g)*
Vg = *grain volume (cm^3)*

The samples were then placed into individual thick walled rubber sleeves and the assembly loaded into a hydrostatic cell. With an ambient pressure (400 psi) applied to the sample, helium held at 100 psi reference pressure was released into the samples pore volume. The resultant pressure drop was used to determine pore volume at ambient.

$$Vb = Vp + Vg$$

$$\text{Ambient Porosity \%} = \frac{Vp}{Vb} x\,100$$

$$\text{Overburden Porosity \%} = \frac{Vp - \Delta Vp}{Vb - \Delta Vp} x\,100$$

where

Vp = *ambient pore volume* (cm^3)
Vb = *ambient bulk volume* (cm^3)
Vg = *grain volume* (cm^3)
ΔVp = *change in pore volume* (cm^3)

Permeability to Air

The samples were placed into a hydrostatic cell (Appendix II) with an ambient confining pressure of 400 psi applied. The confining pressure was used to prevent bypassing of air around the sample when the measurement was made. In order to determine permeability a known air pressure was applied to the upstream face of each sample, creating a flow of air through the core plug. Air permeability for each core sample was calculated using Darcy's Law through knowledge of the upstream pressure, flow rate, viscosity of air and sample dimensions.

$$Ka = \frac{2000.BP.\mu.q.L}{(P_1^2 - P_2^2).A}$$

where

Ka = *air permeability (milliDarcy's)*
BP = *barometric pressure (atmospheres)*
μ = *gas viscosity (cP)*
q = *flow rate* (cm^3/s)
L = *sample length (cm)*
P_1 = *upstream pressure (atmospheres)*
P_2 = *downstream pressure (atmospheres)*
A = *sample cross sectional area* (cm^2)

CHAPTER 3

SAMPLE PREPARATION AND BASE PARAMETER DETERMINATIONS

3.2 Test Results

3.2.1 CT Scanning

PE907926

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The enclosure PE907926 is enclosed within the container PE907925 at this location in this document.

The enclosure PE907926 has the following characteristics:

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SUBTYPE =	PHOTOGRAPH
DESCRIPTION =	Western Underground Gas Storage Pty Ltd CT Scans (enclosure from Special Core Analysis and Petrological Final Report--attachment to WCR) for Iona-1
REMARKS =	
DATE_CREATED =	22/12/98
DATE_RECEIVED =	24/12/88
W_NO =	W970
WELL_NAME =	Iona-1
CONTRACTOR =	ACS Laboratories Pty Ltd
CLIENT_OP_CO =	Western Underground Gas Storage Pty Ltd

(Inserted by DNRE - Vic Govt Mines Dept)

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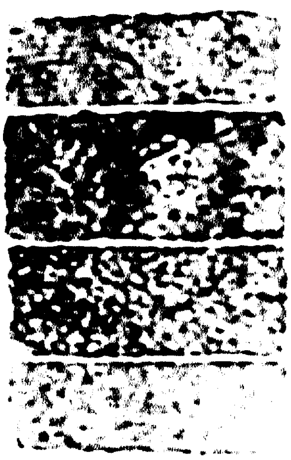
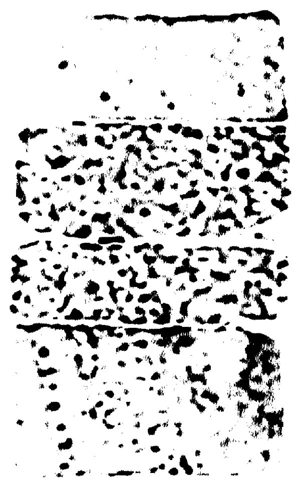


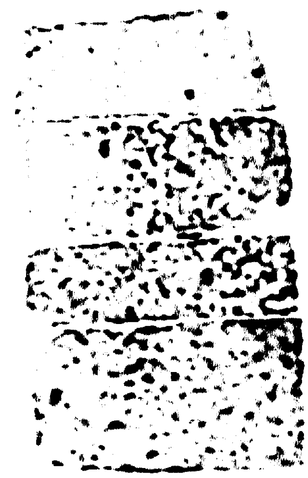
0°

90°

Sample No : Stack No. 1



0°



90°

Sample No: Stack No. 2

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CHAPTER 4

CRITICAL THROUGHPUT ANALYSES

4.1 Test and Calculation Procedures

4. CRITICAL THROUGHPUT ANALYSES

4.1 Test and Calculation Procedures

4.1.1 Brine Saturation

The two stacks were initially vacuum saturated with 25000 ppm NaCl equivalent brine followed by pressure saturation at 2000 psi for a minimum of 12 hours. To determine complete saturation, the pore volume of each stack was ascertained by mass balance and compared with that of porosimetry. Saturation levels were with ± 2% (of 100% Sw) and thus deemed suitable to proceed with the scheduled analyses.

4.1.2 Single Point Drainage Capillary Pressure

Both stacks were driven to residual water saturation by the centrifuge capillary pressure technique. The saturated samples were placed in individual drainage cups under air and loaded into a Spintron GT-15 centrifuge and, as standard practices require[1], were left at an induced capillary pressure for 24 hours. Volumes of brine displaced were monitored as a function of time. The induced capillary pressures were calculated as below[2].

$$Pc = \frac{1}{2} \Delta \rho \omega^2 (r_2^2 - r_1^2) \ x \ (1.013 \, x \, 14.696 \, x \, 10^{-6})$$

where	Pc	=	*capillary pressure at the inlet face of the core (psi)*
	$\Delta \rho$	=	*density difference of the two fluids, i.e. air and water (g/cm^3)*
	ω	=	*angular velocity (rad/s)*
		=	*2π (RPM)/60*
	r_2	=	*radius from the centre of the centrifuge to the bottom of the core plug (cm)*
	r_1	=	*radius from the centre of the centrifuge to the top of the core plug (cm)*

---

1 Omoregie, Zuwa (March 1988), "Factors Affecting the Equivalency of Different Capillary Pressure Measurement Techniques", S. Chevron Oilfield Research Co., *SPE Formation Evaluation*, pp. 147-155.

2 Hassler, Brunner (1945), "Measurement of Capillary Pressures in Small Core Samples", *AIME* Vol. 160, pp. 114-123.

4.1.3 Permeability to Air at Residual Water Saturation

Each stack was mounted into a hydrostatic core holder and an effective overburden pressure of 1000 psi applied. Humidified air was flowed through the samples, to prevent drying out, and allowed to stabilise. A pressure transducer was connected to the system to allow accurate permeability determinations. The permeability to air at residual water saturation of the separate stacks was calculated as described in section 3.1.5 of this report. The two stacks were then combined into one and the permeability to air at residual water saturation of the composite stack calculated. This stack was then placed in an oven and allowed to stabilise at the reservoir temperature of 134°F. The permeability to air at residual water saturation of the composite stack at reservoir conditions was then calculated.

4.1.4 Critical Throughput Analyses

Four separate throughput analyses were performed on the stack at reservoir conditions. The first, a throughput to gas at residual water saturation, consisted of flowing humidified air through the stack at a reservoir equivalent (40 Mscf/day) flow rate scaled to laboratory conditions. A Druck pressure transducer was used to measure the upstream pressure directly from the core face. The permeability to air at approximately half-hour intervals was calculated using a mini-Buck electronic flowmeter to measure the high flow rates attained. The total time for each throughput was approximately eight hours.

A water trap was placed in line at the outlet to collect produced fines. Effluent samples were collected for each of the four throughputs.

The remaining throughputs required flowing humidified air and brine at discrete water-gas ratios. These ratios were scaled to laboratory flow rates from information supplied by Western Underground Gas Storage Pty Limited (10, 20 and 30 bbl/Mscf). To achieve these water-gas ratios, a Beckman twin piston pump was connected to the gas inlet line and the water-gas flow rates were set using the pump controls and mini-Buck electronic flowmeter. The permeability to gas was calculated as described in the previous paragraph and produced water was collected in a water trap.

4.1.5 Mercury Injection Seal Analysis

Sample offcuts of sufficient volume to fill the sample chamber (circa 2 cm^3) were utilised for capillary pressure determinations by the mercury injection technique. The mercury injection apparatus used was a semi-automatic Micromeritics Autopore 9200 which can operate up to a pressure of 40,000 psia, and can measure intrusions as small as 0.0001 cm^3.

The Micromeritics Autopore records mercury intrusion by measuring the capacitance change between the capillary of mercury contained in the penetrometer and an outer metal sheath as mercury invades the samples. For pressures up to 24 psia, air pressure was used. Hydraulic oil was used to achieve the higher pressures. No volume corrections for pressure effects were made, since below 24 psia they are negligible, whilst for higher pressures the penetrometer experiences equal external and internal pressures and mercury compression is offset by penetrometer compression.

All samples were dried in a humidity oven and placed into calibrated glass penetrometers. These consist of a sample chamber and attached precision bore capillary. Once the samples were placed into the penetrometer a vacuum was applied until less than 50 micrometres of mercury had been achieved. Mercury was then introduced into the penetrometer and the run commenced along pre-defined pressure points on a logarithmic scale. After equilibration at each pressure point a capacitance reading was taken which was then converted into an equivalent intrusion volume.

Pore throat diameter for intrusion pressure can be calculated as such:

$$D = \frac{4\,T \cos\theta\; C}{P_c}$$

where D = *pore throat diameter (microns)*
T = *interfacial tension (dynes/cm)*
θ = *contact angle (degrees)*
P_c = *capillary pressure (psi)*
C = *conversion constant*
= 145×10^{-3}

Any apparent inconsistencies between the reported values of Intrusion (percent) and Saturation (percent) are a rounding effect. All intrusion however cumulates to 100% saturation at maximum pressure.

Displacement or breakthrough pressure can be determined by two methods. From the capillary pressure curves where the saturation tends to plateau, a point on the pressure axis can be read as indicated on the plots provided. Similarly, from an intrusion plot, the diameter at which breakthrough occurs can be read off the x-axis also as indicated. Both techniques are interpretative only.

CHAPTER 4

CRITICAL THROUGHPUT ANALYSES

4.2 Test Results

4.2.1 Permeability Summary

PERMEABILITY SUMMARY

Client Western Underground Gas Storage Pty Limited

Well Iona-1

Overburden 1000 psi

Stack Number	Depth (metres)	Porosity (percent)	Permeability to Air (milliDarcy's)	Residual Water Saturation (percent)	Permeability to Air at Residual Water saturation	
					Ambient Temperature (70ºF) (milliDarcy's)	Reservoir Temperature (134ºF) (milliDarcy's)
1	1306.9-1312.4	24.5	14176	8.5	13659	-
2	1306.9-1312.4	23.9	11132	8.2	10991	-
Composite	1306.9-1312.4	24.2*	-	8.4*	10199	10217

* Denotes average values

CHAPTER 4

CRITICAL THROUGHPUT ANALYSES

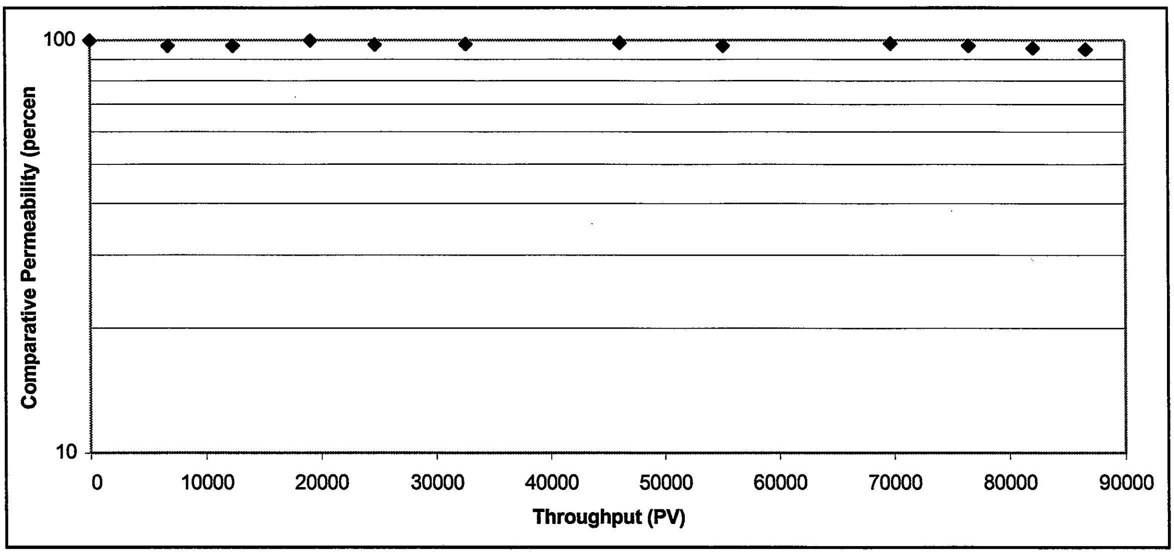
4.2 Test Results

4.2.2 Critical Throughput Analyses

CRITICAL THROUGHPUT

Client	Western Underground Gas Storage Pty Limited		
Well	Iona-1		
Sample	Stack	**Depth**	1306.9-1312.4 m
Overburden	1000 psi	**Permeability**	10217 milliDarcy's
Temperature	134°F	**Porosity**	24.2 percent
Equivalent Reservoir Flow Rates		40Mscf/d gas	

Flow Rate (L/min)	Time (minutes)	Throughput (PV)	Normalised Air Permeability (milliDarcy's)	Comparative Permeability (percent of Original)
Reservoir Equivalent	0	0	10217	100
	30	6750	9931	97
	55	12375	9931	97
	85	19125	10219	100
	110	24750	9996	98
	145	32625	10023	98
	205	46125	10082	99
	245	55125	9911	97
	310	69750	10055	98
	340	76500	9913	97
	365	82125	9801	96
	385	86625	9729	95
	405	91125	9904	97

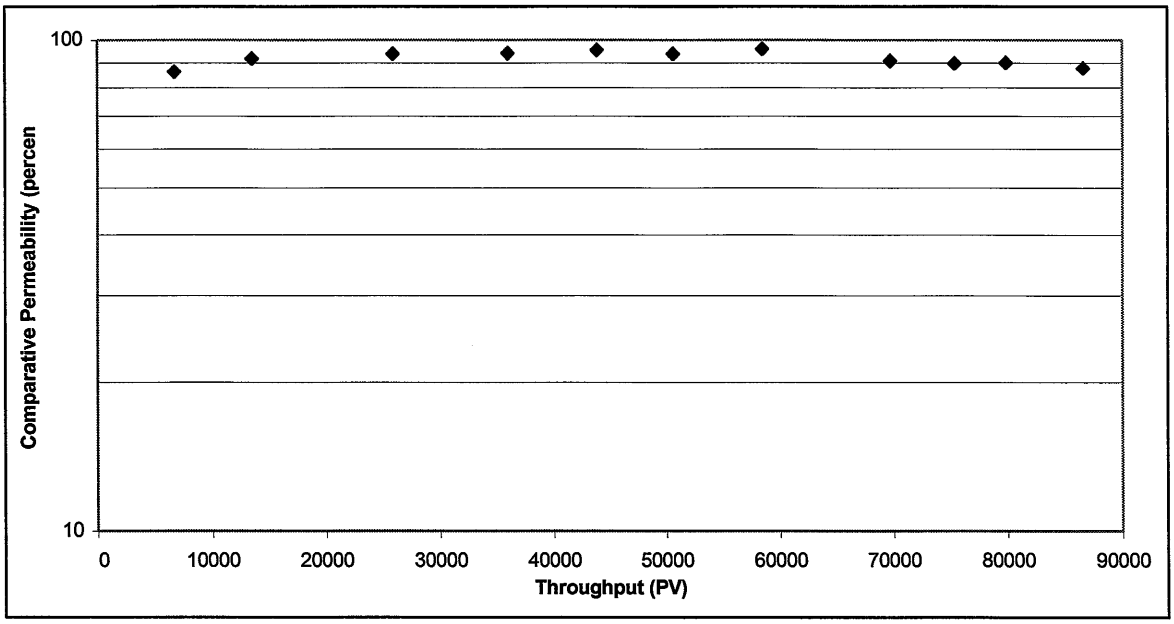


CRITICAL THROUGHPUT

Client	Western Underground Gas Storage Pty Limited		
Well	Iona-1		
Sample	Stack	**Depth**	1306.9-1312.4 m
Overburden	1000 psi	**Permeability**	10217 milliDarcy's
Temperature	134°F	**Porosity**	24.2 percent

Equivalent Reservoir Flow Rates 40Mscf/d gas; 10bbl/Mscf water

Flow Rate (L/min)	Time (minutes)	Throughput (PV)	Normalised Air Permeability (milliDarcy's)	Comparative Permeability (percent of Original)
Reservoir Equivalent	30	6750	8804	86
	60	13500	9373	92
	115	25875	9587	94
	160	36000	9620	94
	195	43875	9733	95
	225	50625	9591	94
	260	58500	9808	96
	310	69750	9270	91
	335	75375	9165	90
	355	79875	9187	90
	385	86625	8962	88

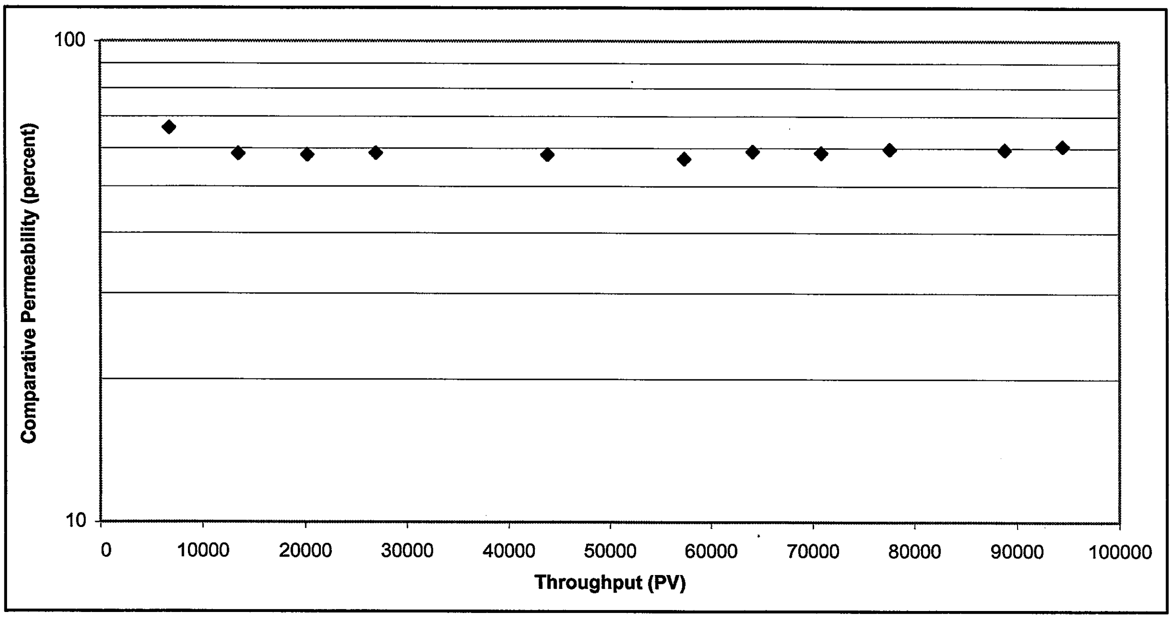


CRITICAL THROUGHPUT

Client	Western Underground Gas Storage Pty Limited		
Well	Iona-1		
Sample	Stack	**Depth**	1306.9-1312.4 m
Overburden	1000 psi	**Permeability**	10217 milliDarcy's
Temperature	134°F	**Porosity**	24.2 percent

Equivalent Reservoir Flow Rates 40Mscf/d gas; 20bbl/Mscf water

Flow Rate (L/min)	Time (minutes)	Throughput (PV)	Normalised Air Permeability (milliDarcy's)	Comparative Permeability (percent of Original)
Reservoir Equivalent	30	6750	6767	66
	60	13500	5978	59
	90	20250	5951	58
	120	27000	5998	59
	195	43875	5943	58
	255	57375	5836	57
	285	64125	6044	59
	315	70875	6005	59
	345	77625	6108	60
	395	88875	6090	60
	420	94500	6187	61

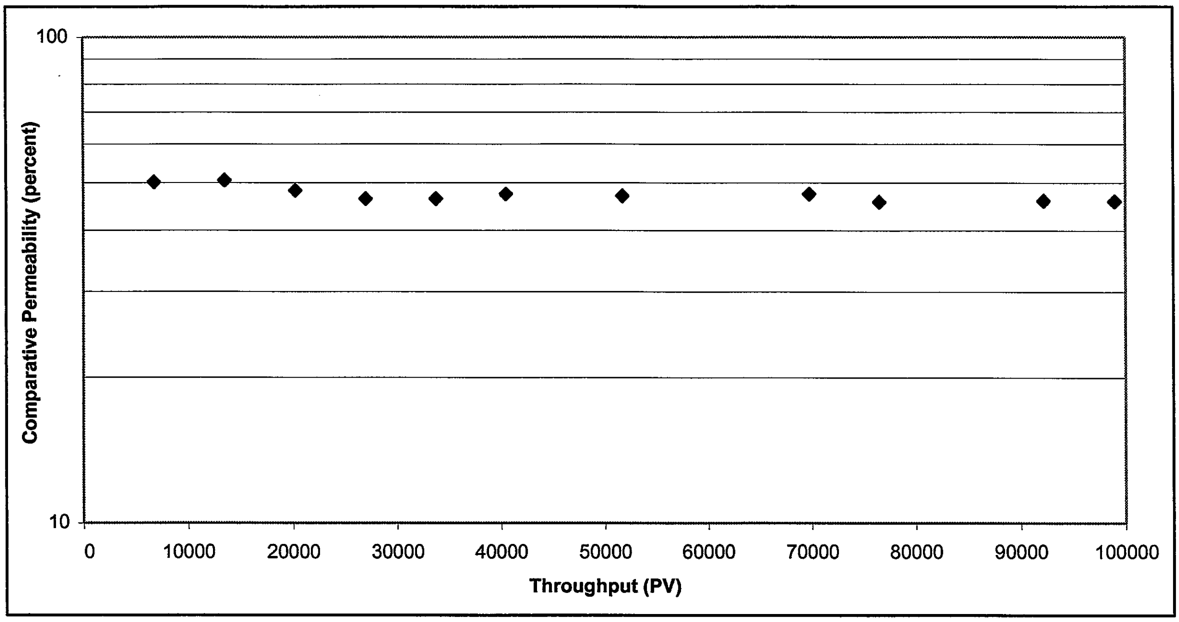


CRITICAL THROUGHPUT

Client	Western Underground Gas Storage Pty Limited		
Well	Iona-1		
Sample	Stack	**Depth**	1306.9-1312.4 m
Overburden	1000 psi	**Permeability**	10217 milliDarcy's
Temperature	134°F	**Porosity**	24.2 percent

Equivalent Reservoir Flow Rates 40Mscf/d gas; 30bbl/Mscf water

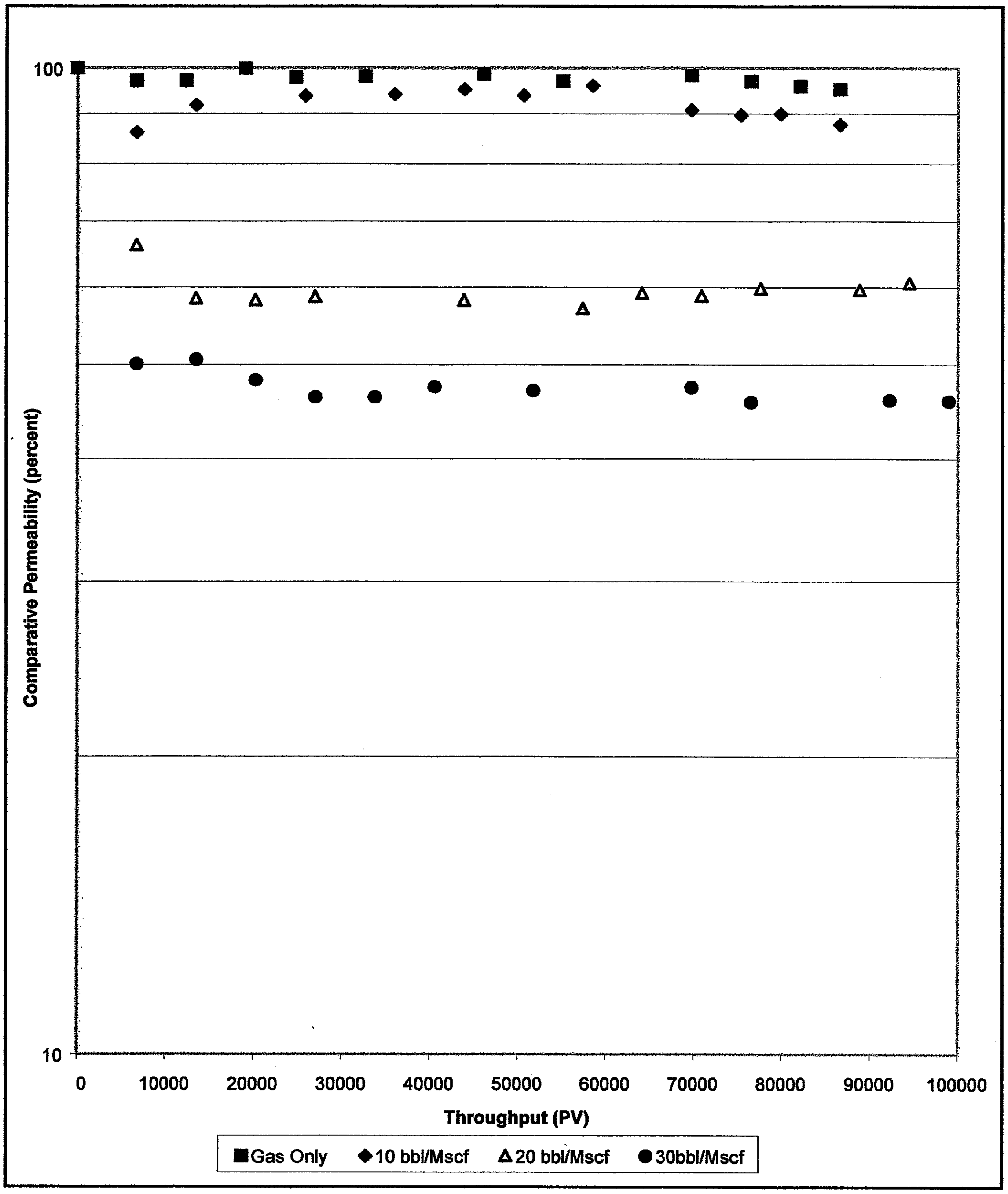
Flow Rate (L/min)	Time (minutes)	Throughput (PV)	Normalised Air Permeability (milliDarcy's)	Comparative Permeability (percent of Original)
Reservoir Equivalent	30	6750	5122	50
	60	13500	5173	51
	90	20250	4931	48
	120	27000	4736	46
	150	33750	4736	46
	180	40500	4850	47
	230	51750	4810	47
	310	69750	4846	47
	340	76500	4676	46
	410	92250	4700	46
	440	99000	4690	46



CRITICAL THROUGHPUT

Client	Western Underground Gas Storage Pty Limited		
Well	Iona-1		
Sample	Stack	**Depth**	1306.9-1312.4 m
Overburden	1000 psi	**Permeability**	10217 milliDarcy's
Temperature	134°F	**Porosity**	24.2 percent

Equivalent Reservoir Flow Rates 40Mscf/d gas + water (see legend)



CHAPTER 4

CRITICAL THROUGHPUT ANALYSES

4.2 Test Results

4.2.4 Mercury Injection Seal Analysis

CAPILLARY PRESSURE

Client	Western Underground Gas Storage Pty Limited
Well	Port Campbell-2
Test Method	Air/Mercury Capillary Pressure Drainage
Depth	8174' 0"

Pressure (psia)	Intrusion (percent)	Saturation (percent)	Pore Diameter (μm)
1.78	0.0	0.0	119
2.43	0.0	0.0	87.2
2.88	0.0	0.0	73.6
3.44	0.0	0.0	61.6
4.08	2.3	2.3	52.0
4.86	0.0	2.3	43.6
5.80	0.0	2.3	36.6
6.94	0.0	2.3	30.5
8.30	0.0	2.3	25.5
9.92	4.7	7.0	21.4
11.8	2.3	9.3	18.0
14.1	2.3	11.6	15.0
16.9	0.0	11.6	12.5
20.2	2.3	14.0	10.5
24.1	2.3	16.3	8.79
28.8	0.0	16.3	7.35
33.9	7.0	23.3	6.26
40.5	2.3	25.6	5.23
48.3	0.0	25.6	4.39
57.6	0.0	25.6	3.68
69.0	0.0	25.6	3.07
82.7	2.3	27.9	2.56
98.8	0.0	27.9	2.15
117	2.3	30.2	1.81
141	0.0	30.2	1.50
168	0.0	30.2	1.26
201	2.3	32.6	1.05
240	0.0	32.6	0.882

Pressure (psia)	Intrusion (percent)	Saturation (percent)	Pore Diameter (µm)
287	0.0	32.6	0.740
342	0.0	32.6	0.619
413	2.3	34.9	0.513
489	0.0	34.9	0.434
588	2.3	37.2	0.360
697	0.0	37.2	0.304
833	0.0	37.2	0.254
999	2.3	39.5	0.212
1193	0.0	39.5	0.178
1427	0.0	39.5	0.149
1707	2.3	41.9	0.124
2042	0.0	41.9	0.104
2445	2.3	44.2	0.0867
2925	0.0	44.2	0.0725
3516	2.3	46.5	0.0603
4151	0.0	46.5	0.0511
4966	2.3	48.8	0.0427
5929	0.0	48.8	0.0358
7126	2.3	51.2	0.0298
8488	2.3	53.5	0.0250
10175	2.3	55.8	0.0208
12056	0.0	55.8	0.0176
14418	4.7	60.5	0.0147
17250	2.3	62.8	0.0123
20679	4.7	67.4	0.0103
24691	7.0	74.4	0.0086
29630	7.0	81.4	0.0072
35424	11.6	93.0	0.0060
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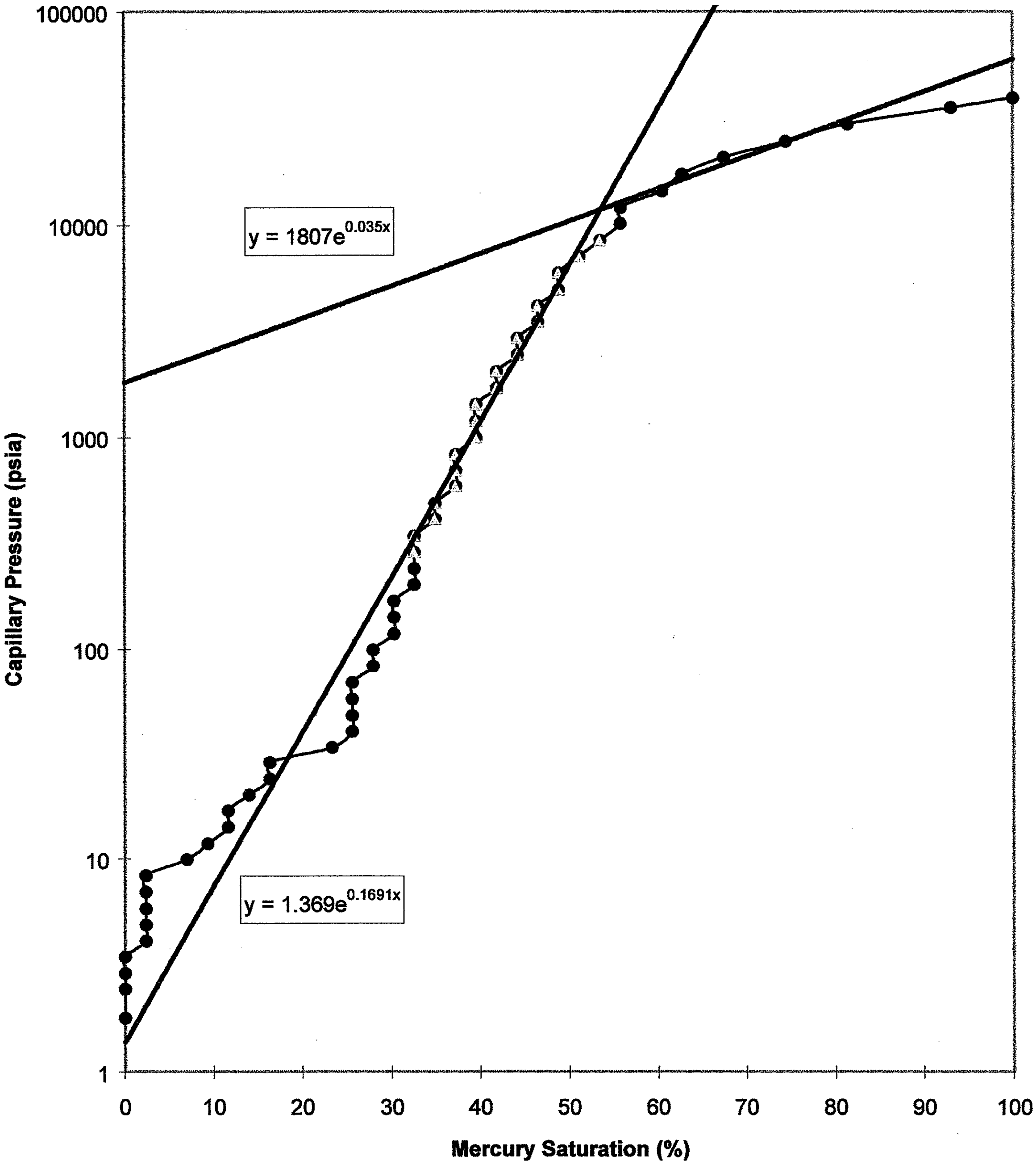
CAPILLARY PRESSURE

DEPT. NAT. RES & ENV
PE907927

Client Western Underground Gas Storage Pty Limited
Well Port Campbell-2

Test Method Air/Mercury Capillary Pressure Drainage

Depth 8174' 0"



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CONTRACTOR = ACS Laboratories Pty Ltd
CLIENT_OP_CO = Western Underground Gas Storage Pty Ltd

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PORE SIZE DISTRIBUTION

Client Western Underground Gas Storage Pty Limited
Well Port Campbell-2

Test Method Air/Mercury Capillary Pressure Drainage

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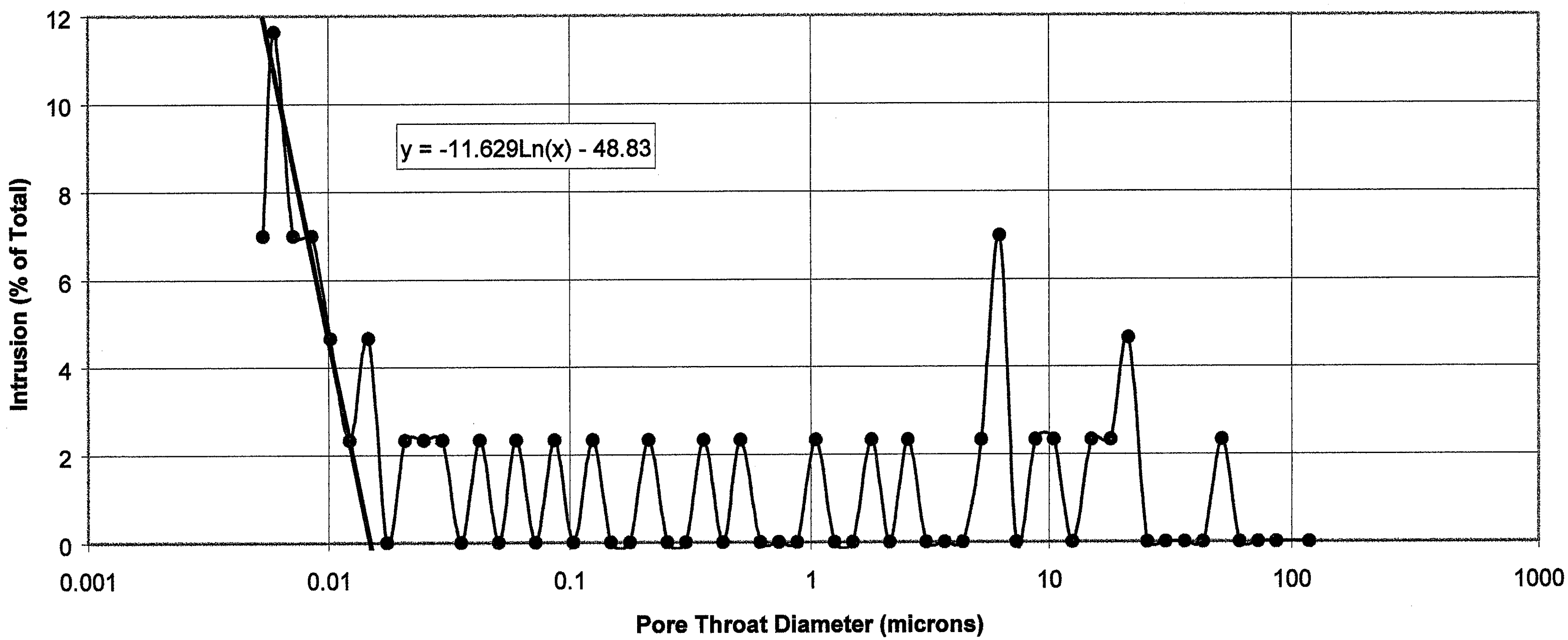

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CHAPTER 5

PETROLOGY

5.1 Test and Calculation Procedures

5. PETROLOGY

5.1 Test and Calculation Procedures

5.1.1 Executive Summary

Western Underground Gas Storage Pty Limited submitted three off-cut core samples from Iona-1 well for petrographic analysis including detailed thin section description and scanning electron microscopy to show the effect with organic compounds on the pore spaces and the migration of the fine crystallites.

One sample was selected to represent a set of samples submitted for Special Core Analysis (SCA). It ranges from coarse to very coarse grains and contains local pebble size grains. Most of the grains are subrounded to rounded. Textural maturity is, in general, coarse-grained quartz arenite. Fabric in the sample is massive. The sample is a clean sandstone with minor to trace amounts of detrital depositional matrix and trace amounts of authigenic clay cements.

The sample contains trace amounts of feldspar and lithic grains. Framework composition is dominated by monocrystalline quartz with minor polycrystalline quartz, traces of low grade metamorphic and sedimentary rock fragments. Quartz grains are subrounded to rounded and exhibit strong to slightly undulose extinction with few coarse grains showing straight undulose extinction. Feldspar is mainly potassic in origin and partially to completely dissolved. Metaquartzite is the main lithic with trace to rare amounts rounded sedimentary chert. The heavy mineral suite includes mainly tourmaline and very rare rutile, most of which occur within the detrital quartz grains. Although detrital matrix is entirely absent, mud infiltration from the drilling fluid is present as pore fill and grain coating. Dispersed organic matter is very rare in the samples. This sandstone is classified as quartz arenite.

The sample was probably deposited by high energy sedimentation that could range from fluvial to estuarine/tidal channel. The presence of high amounts of monocrystalline quartz and traces of metamorphic and sedimentary rock fragments is interpreted to reflect contribution from a cratonic region.

Authigenic minerals are minor to trace and dominated by quartz cement and traces of pyrite and kaolinite. Authigenic quartz occurs mainly as euhedral overgrowths on detrital grains. Authigenic kaolinite occurs as randomly oriented pseudo-hexagonal, vermiform and face-to-face, book-like species around highly altered potassium feldspar and mica suggesting an alteration product of potassium feldspar. Kaolinite crystals occupy little of the intergranular pore space and contain microporosity. Other authigenic minerals are of minor to trace amounts. Framboidal pyrite occurs in as spheroidal aggregates of discrete, equigranular microcrysts; less than 1 μm in size. The framboidal pyrite is associated with organic-matter.

Early diagenetic minerals include framboidal pyrite which was deposited during the early sulphate reduction. Kaolinite was precipitated as a mid-diagenetic mineral, sometimes replacing feldspar and mica. Authigenic quartz overgrowths could have formed simultaneously with the authigenic kaolinite. These events have occurred in the mid to late stages of the diagenetic history and was followed by the hydrocarbons entrapment.

Reservoir potential of the sample is excellent. The framework grains show few suture to concavo-convex contacts suggesting the effect of compaction process in destroying the reservoir quality. Compaction has destroyed around 40% of the primary intergranular porosity. Meanwhile cementation of authigenic minerals has much less effect on the reservoir quality and has contributed to the porosity loss by around 7%. Both mechanisms have reduced 48% of the primary intergranular porosity. Visible porosity is 24.4%, most of which is primary intergranular porosity (20.8%). Secondary porosity is much less (3.6%) and is present as elongated and enlarged pores which have resulted from partial to complete dissolution of feldspar grains and fracturing.

SEM observations revealed that sandstones from Iona-1 contain minor to trace amounts of clay most of which is kaolinite. Kaolinite is mostly of authigenic origin and occurs as pseudohexagonal booklets and vermiform crystals around altered potassium feldspar and mica, indicating direct relation between these components. Kaolinite crystals range in grain size from few microns up to 20 μm. SEM also revealed that the pore and pore throat size ranges from 50 to 200 μm. Therefore migration of fine crystallites during the fluid movement and extraction should be minimal, since the pore and pore throat size is much larger than the kaolinite crystals. On the other hand, altered feldspar grains may move to block some of the pores and pore throat. The effect of feldspar movement is very low, since feldspar is present in trace to minor amounts (~ 2.0%).

Whilst performing the Special Core Analysis (SCA) experiment traces of fine crystallites were removed from the sample. Detailed SEM-EDS grain size and chemical analyses of the produced effluent indicate that these fine particles range in size from sub-micron up to 20 mm. They predominantly comprise Fe as FeO_3 from the rusty material on the surface of the sandstone samples, Al and Si which is consistent with kaolinite, Cl and Na corresponding brine (NaCl), and S and Fe which probably represents fine framboidal pyrite.

5.1.2 Introduction

Western Underground Gas Storage Pty Limited submitted three off-cut core samples from the Iona-1 well for a petrographic study involving detailed thin section description. Detailed thin section description was carried out on one selected sample and SEM studies were carried out on two samples. The sample studied petrographically was taken from the edge of a set of plugs, to demonstrate the effect of flowing gas and brines on fine crystallites migration. The following is a summary of the aims of this study:

- undertake thin section descriptions to include sediment classification, description of texture and composition.

- verify clay types, texture, grain size, shape, pore throat shape, clay matrix and pore bridging/grain coating clay identification using scanning electron microscope (SEM). SEM was used specifically to examine whether any damage effects could have occurred, in particular the morphology of the clay minerals. Particular attention was paid to observing:

  a) migration and/or mushing of fine clay crystallites in the pore space

  b) corrosion and/or dissolution of framework grains or authigenic phases

  c) change of habit of existing phases by collapse or swelling

- presentation of a sediment provenance, style and extent of diagenetic modification and reservoir potential.

- determine the petrographic properties of the samples which control reservoir behaviour characteristics identified through Special Core Analysis (SCA) properties. In particular the effect of cleaning on fines migration.

5.1.3 Methods

Samples were supplied as off-cuts of core materials. One thin section was prepared and cut perpendicular to the bedding plane. The sample was impregnated with blue-stained araldite prior to thin section preparation in order to facilitate porosity recognition. The modal composition for the studied sample was determined using standard techniques (Zuffa, 1985; Pettijohn et al. 1987) and by counting 500 points.

The thin section was stained with Alizarin Red-S and potassium ferricyanide to aid different carbonate assemblages identification (Dickson, 1965) and was stained with sodium cobaltinitrite to differentiate potassium feldspar from plagioclase (Lainz et al. 1964). Classification of clastic rocks was based on the relative proportion of detrital quartz, feldspar and rock fragments (Folk, 1974). Other detrital components, such as mica and heavy minerals, as well as all authigenic phases, are not included in the common sandstone classification. The type of porosity is reported according to the classification of Schmidt and McDonald (1979).

A scanning electron microscope equipped with an energy-dispersive X-ray system (SEM-EDS) was used to study two selected samples: # 2 (1307.50 m) and # 6 (1312.40 m). Samples were examined as fracture mounts. Another sample was studied after treatment with brines. The sample was filtrated to examine the chemistry, grain size and nature of mobile grains. The sample was then examined under SEM-EDS after cutting a piece of the filter paper and attaching to SEM stump.

CHAPTER 5

PETROLOGY

5.2 Test Results

5. PETROLOGY

5.2 Test Results

5.2.1 Lithology

The Iona-1 sandstone sample is composed mostly of quartz with minor lithic fragments and almost no feldspar. The lack of depositional matrix in the sample strongly suggests a high energy sedimentation. The average grain composition of the studied sample is $Q_{95.6}$ $F_{2.5}$ $R_{1.9}$. The Iona-1 sandstone sample is classified as quartz arenite, (Fig. 1).

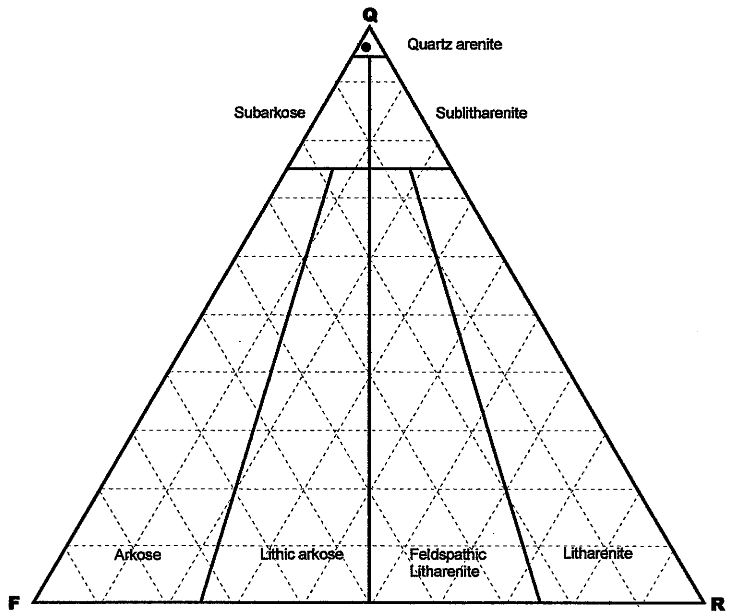

Figure 1: QFR ternary diagram showing the present-day framework grain composition of Iona-1 sand sample. The sand sample from Iona-1 is classified as quartz arenite, (after Folk, 1974).

5.2.2 Texture

The sample cut is light grey, massive, grain supported, moderately to well sorted, coarse to very coarse-grained sandstone. Detrital depositional matrix content is absent and most of the grains are subrounded to rounded. Trace authigenic minerals and considerable amounts of visual porosity (Plate 1) are present. Visible porosity is patchily distributed and comprises mainly primary intergranular pores and minor secondary grain dissolution. The sample is characterised by strongly homogeneous grain fabrics. It exhibits a fining-upward sequence implying a high energy fluvial to shoreface and possible tidal channel sedimentation.

Detrital grains range typically from subrounded to rounded. Quartz grains are subrounded to well rounded. The sample underwent minor compaction leading to a predominance of point and straight grain contacts between detrital grains. Ductile deformation during early burial is evident in ductile lithic grains, some mica flakes, and patches of detrital matrix.

5.2.3 Composition

The framework component is dominated by monocrystalline quartz (68.6% Table 1). Monocrystalline quartz commonly displays straight to slightly undulose extinction and rarely contains vacuoles and trains of vacuoles. Mineral inclusions in quartz grains are rare and comprise acicular rutile or prismatic tourmaline. Polycrystalline quartz grains are present in minor to trace amounts (0.8% Table 1). Polycrystalline quartz grains predominantly occur as equant to subequant rounded coarse grains and display strong undulose extinction.

The sample contains minor feldspar (1.8%, Table 1). Feldspar grains are mainly orthoclase with traces of microcline. Lithic grains are another minor component (1.4%) and comprise metaquartzite, with trace to rare amounts of rounded sedimentary chert. Brown and blue tourmaline and zircon are found as accessory minerals. Tourmaline mainly occurs in many of the detrital monocrystalline quartz grains.

Clay depositional matrix is entirely absent (Table 1). Organic matter with common finely dispersed framboidal pyrite is present in trace to rare amounts.

Authigenic phases are dominated by quartz overgrowths (2.4%, Plate 2) and traces of authigenic kaolinite (0.6%, Table 1) and pyrite. Pyrite occurs as spheroidal aggregates of discrete, equigranular microcrysts; less than one µm in size.

Porosity is common and scattered throughout the sample (24.4%), usually as triangular pores between detrital and authigenic minerals (Plate 2), suggesting a primary origin (20.8%). Secondary porosity is less common than the primary pores (3.6%). It includes enlarged pores and elongated pores providing good connections between the larger pores. There is minor microporosity between kaolinite booklets.

TABLE 1: Composition of Iona-1 core sample. All values are in per cent based on 500 point counts.

Quartz (Mono)	68.6
Quartz (Poly)	0.8
K feldspar	1.8
Plagioclase	0.0
Sedimentary Rock Fragments	Tr
Metamorphic Rock Fragments	1.4
Volcanic Rock Fragments	0.0
Mica	0.0
Depositional Matrix	0.0
Siderite	0.0
Quartz Cement	2.4
Kaolinite	0.6
Pyrite	Tr
Organic Matter	Tr
Accessory Minerals	0.0
Primary Porosity	20.8
Secondary Porosity	3.6
Total Porosity	24.4

5.2.4 Scanning Electron Microscopy (SEM)

General Observations

The samples comprise clean coarse to very coarse sandstones with traces of clay mineral assemblages dominated by authigenic kaolinite (Plates 3 and 4). Authigenic kaolinite occurs as pseudohexagonal, vermiform (Plate 5) and book-like species (Plate 6) and occupies few of the intergranular pore spaces (Plate 6). The kaolinite booklets are attached to feldspar grains and mica flakes and they unlikely to move during the fluid extraction. A few large masses of 'ragged edged' materials exhibiting moderately well developed parallel alignment of crystallites coating some of the detrital grains, most likely represent drilling mud (Plate 4). No alteration or corrosion of kaolinite could be detected in this sample. However, many of the detrital quartz grains exhibit some degree of corrosion (Plate 7).

The pores are well interconnected in a 3-D network giving good permeability (Plate 8). The clay minerals are predominantly of authigenic origin. Moderate microporosity is present in the kaolinite cemented areas. Since the size of the pores ranges from 10 to a few hundreds micron, and the size of the kaolinite booklets is around 10 μm, it seems unlikely for the kaolinite booklets to move to block the pore spaces.

Other Observations

Migration and/or mushing of fine clay crystallites in the pore space: Many of the kaolinite crystallites are attached around potassium feldspar and mica flakes, indicating a direct relationship between feldspar and mica alteration, and kaolinite formation. The kaolinite crystals range in diameter from 5 to 10 mm, and it is unlikely to cause formation damage during fluid extraction since the pore sizes are much larger than the sizes of the kaolinite crystal. Comparison with samples prior to treatment may clarify whether the observed grain coatings are migrated fine crystallites or represent part of the reservoir.

Corrosion and/or dissolution of framework grains or cement phases: (None detected). Blocky pore-filling kaolinite (Plates 6 and 7) shows euhedral crystal faces devoid of any indications of grain corrosion, or alteration.

Change of habit of existing phases by collapse or swelling: (None detected). Ragged edged kaolinite displaying embayed margins is common in this sandstone. The embayed margins are typical of some kaolinite morphotypes and are not considered to be due to damage as a result of the cleaning process. No illite/smectite mixed layer was detected.

Cleaning Results

One selected sample has been further examined by scanning electron microscope (SEM) and energy-dispersive X-ray spectroscopy (EDS) to evaluate particle sizes and elemental composition. This allows the phases present to be investigated by analysis of individual particles. This sample was examined to illustrate the effect of fluid movement on the migration of the fine crystallites. After pumping gas and different types of brines into the sample, the powder was collected using filter membrane to provide a suitable sample for individual grain size estimation and microanalysis. The results of SEM-EDS analysis can be summarised as follows:

- Particle sizes range from sub-micron to about 20 μm, with a large amount of discrete material apparent in the approximately 5-20 μm range. Few grains exceeding 20 μm were observed on the filter.

- X-ray microanalysis showed that the major elements of these particles are Fe, Al, Si, and Cl. Minor elements are S, Na, Ca, P, K, Cr, Mn and Ni. The light elements C, and O are not measurable with the current X-ray diffractometer and therefore oxides could not be directly identified.

- Fe (possibly occurs as FeO_3) has probably resulted from the rusty materials on the surface of the original sandstone sample.

- Alumino-silicate: Al & Si which are consistent with kaolinite.

- Major Cl and minor Na are consistent with the brines used for the experiment (25,000 ppm NaCl).

- Minor sulphur with Fe probably represents fine mobile framboidal pyrite.

Diagenesis

Only the major diagenetic events are summarised below. As far as possible, diagenetic processes are discussed in chronological order. The following gives the relative timing of authigenic minerals and other diagenetic modifications observed during petrographic study. The diagenesis of the studied sample can be summarised as follows:

- Early compaction has affected the sample and has resulted in closer packing of grains and parallel alignment of elongated detrital grains.

- Framboidal pyrite could have occurred early in the diagenetic history during the early sulphate reduction.

- Alteration and dissolution of feldspar could have been responsible for the formation of kaolin.

- After kaolin precipitation quartz cements have occurred as overgrowths. The quartz overgrowths postdated or at least formed simultaneously with the precipitation of kaolin.

- Alteration has continued during the later stages of the diagenetic history.

- Minor corrosion and grain dissolution has developed as oversized grain dissolution pores and intragranular porosity.

Reservoir Quality

Reservoir potential of this sample is excellent with high visible porosity (24.4%). Petrographic observations reveal that porosity is present as both primary and secondary pores as well as microporosity. Visible porosity dominantly occurs as primary intergranular porosity (Plates 1, 2 and 9) and has been occluded by both compactional and cementation processes. Compaction was the main agent responsible for reducing the primary intergranular porosity. It has destroyed around 47% of the original primary intergranular porosity (Table 2). All grains have at least three contacts with the neighbouring grains (Plate 10), a criterion indicating mechanically consolidated sandstone. Also, compaction is evident by suture and elongated grain contacts, squeezed grains, rearrangements of some of the detrital grains and some of the grain penetrating relationships. Cementation has contributed to the porosity loss by up to 7% of the primary intergranular porosity (Table 2). Secondary porosity is slightly less common than the primary pores (3.6%) but includes enlarged pores (Plate 9) and elongated pores providing moderate to good connections between the larger pores. Much of the secondary porosity has resulted from fracturing (Plate 9).

Secondary porosity development results from partial to complete dissolution of feldspar (Plate 11) and fracturing (Plate 9). There is a minor amount of infiltrated drilling mud filling some of the pore spaces and coating both detrital and authigenic minerals (Plate 12).

TABLE 2. Compaction and cementation effect on reservoir quality of Iona-1 sandstone sample.

Total Cement	Primary Porosity	IGV	PDTC	PDMC
3.0	20.8	23.8	7.5	40.5

IGV = intergranular volume, PDTC = porosity destroyed by total cement,
PDMC = porosity destroyed by mechanical compaction.

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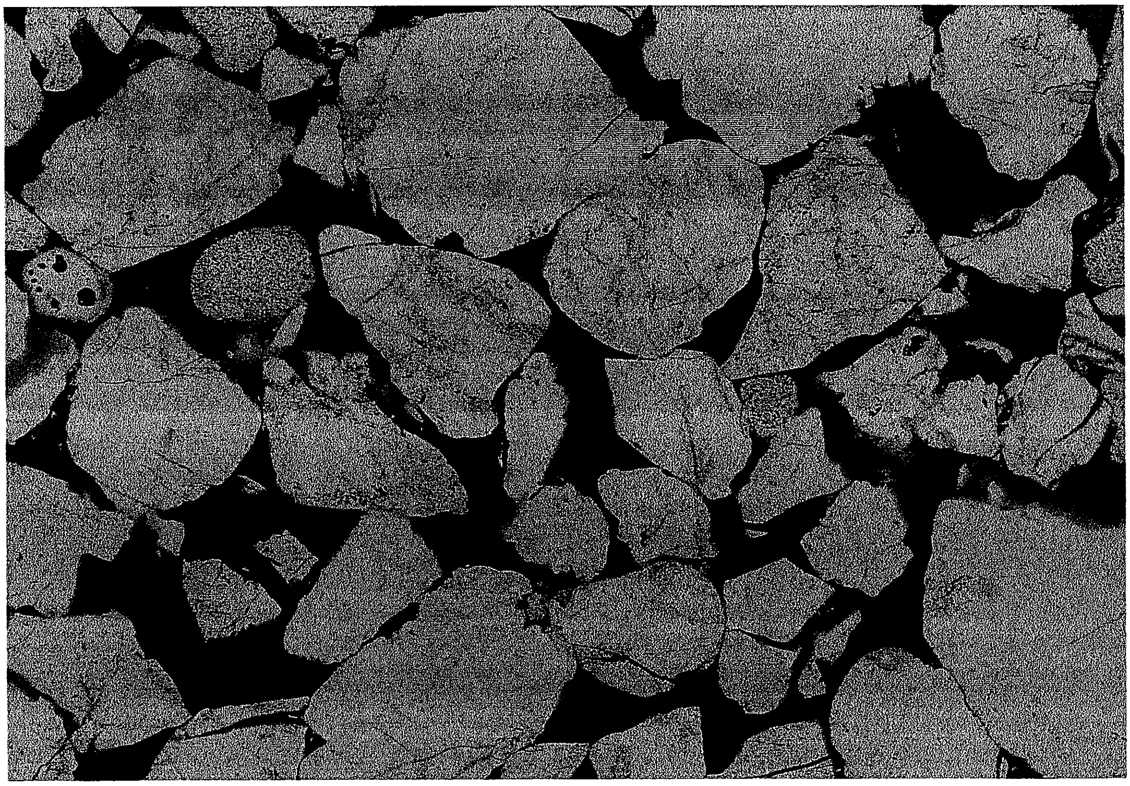

Plate 1: Sample # 2 (1307.50m) Thin section photomicrograph showing general view of quartz arenite with considerable amounts of visual porosity (blue). Plane polarised light. Scale bar = 500 µm.

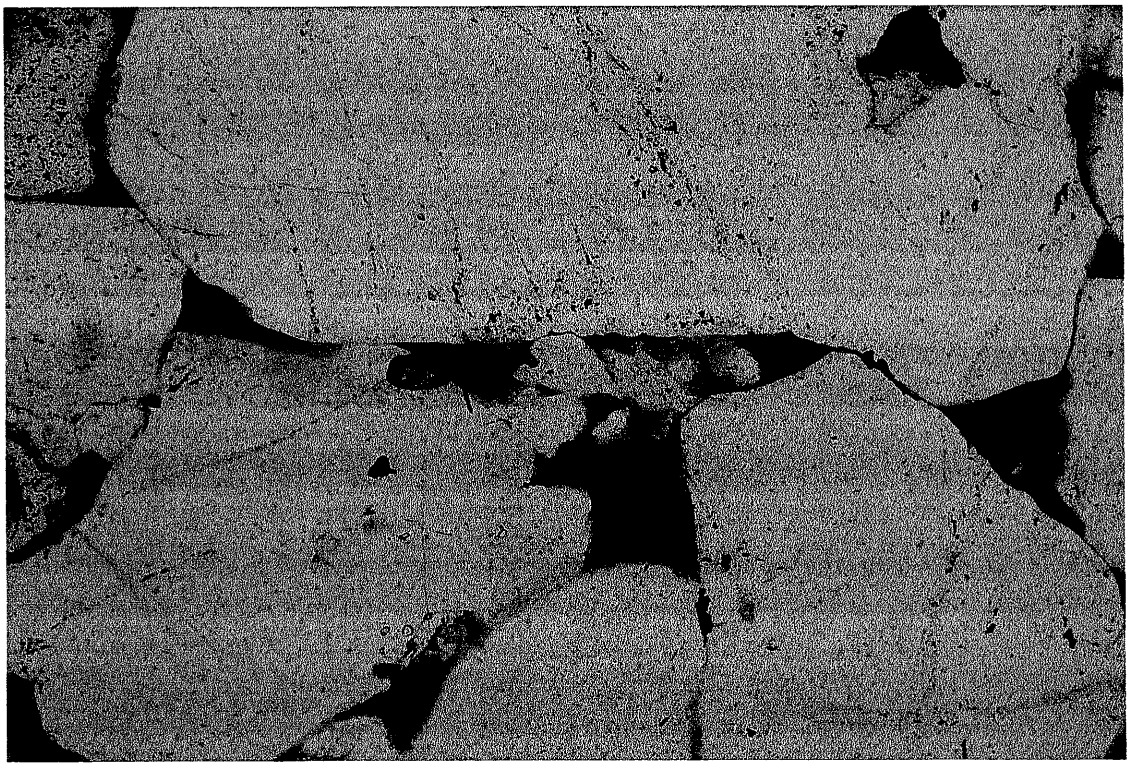

Plate 2 : Sample # 2 (1307.50m) Thin section photomicrograph showing common visual porosity which is scattered throughout the sample, usually as triangular pores between detrital and authigenic minerals, suggesting a primary origin. Note the presence of trace to minor amounts of quartz overgrowth. Note also the presence of zircon. Plane polarised light. Scale bar = 200 µm.

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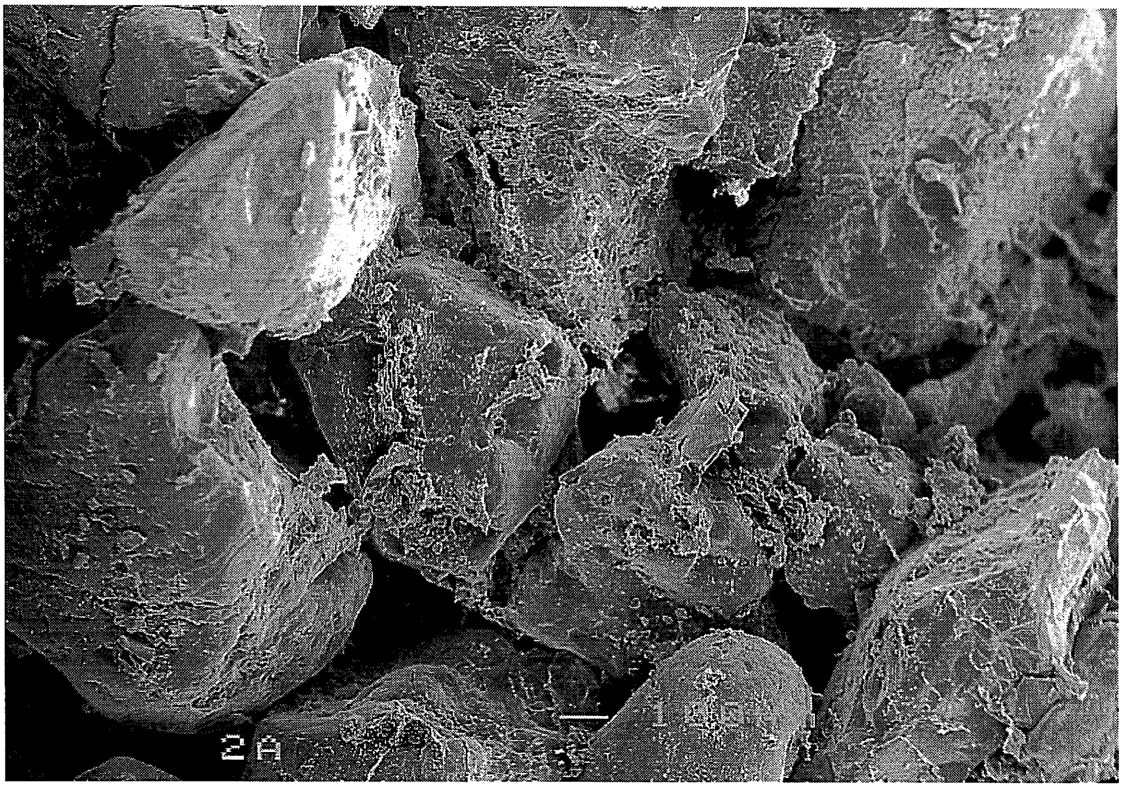

Plate 3: Sample # 2 (1307.50m) SEM photomicrograph showing general view of clean coarse to very coarse sandstones with traces of clay mineral assemblages dominated by authigenic kaolinite. Scale bar = 10 μm.

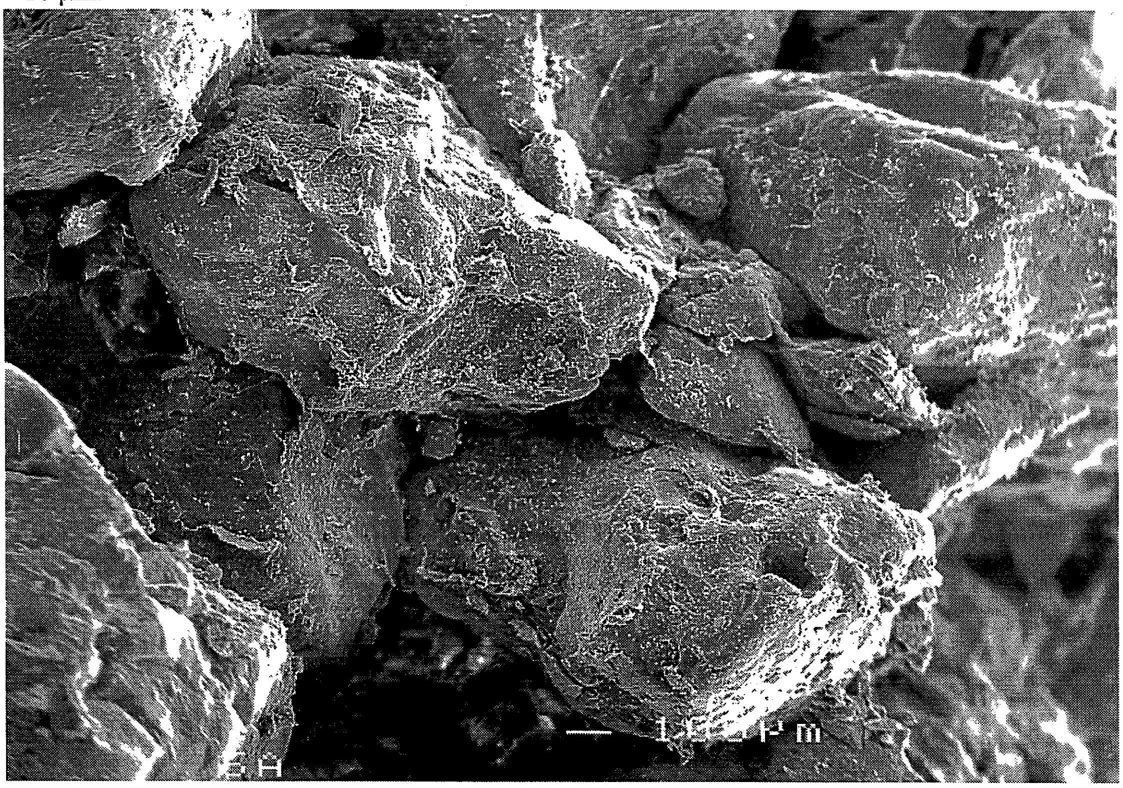

Plate 4: Sample # 6 (1312.40m) SEM photomicrograph showing general view of clean coarse to very coarse sandstones with traces of clay mineral assemblages dominated by authigenic kaolinite. Note the presence of a few large masses of 'ragged edged' materials exhibiting moderately well developed parallel alignment of crystallites coating some of the detrital grains, most likely represent drilling mud. Scale bar = 10 μm.

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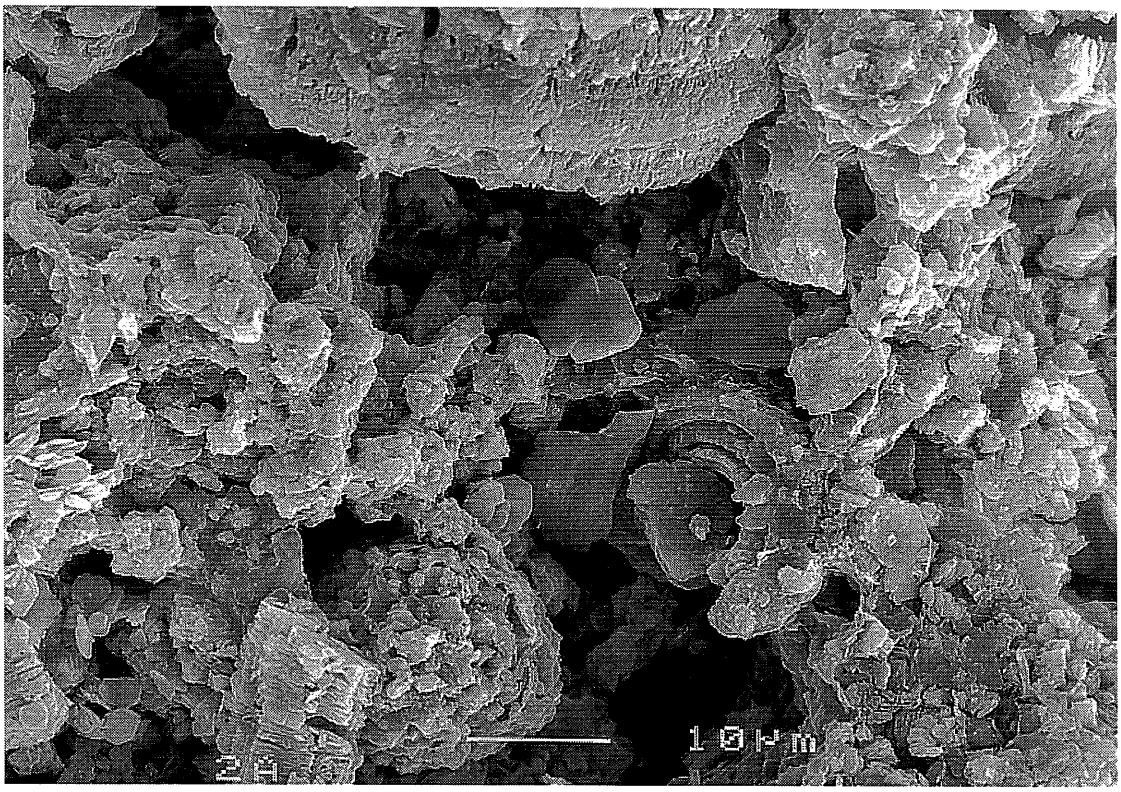

Plate 5: Sample # 2 (1307.50m) SEM photomicrograph of pore filling vermiform kaolinite exhibits well developed vermiform habits. The absence of etch pits indicates that no discernible pitting, corrosion or etching has occurred during the cleaning process. Scale bar = 10 µm.

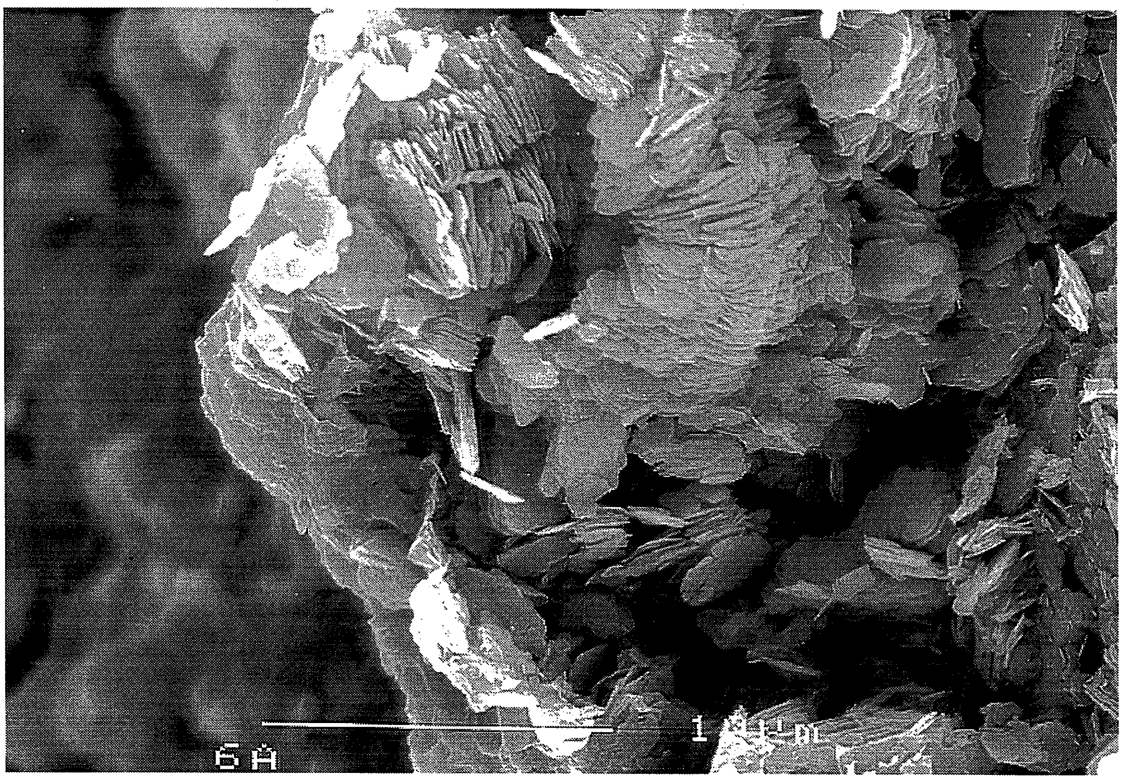

Plate 6: Sample # 6 (1312.40m) SEM photomicrograph showing well developed pseudo-hexagonal and book-like species of authigenic kaolinite which occupies few pore spaces. The kaolinite booklets are attached to feldspar grains and they unlikely to move during the fluid extraction. Scale bar = 10 µm.

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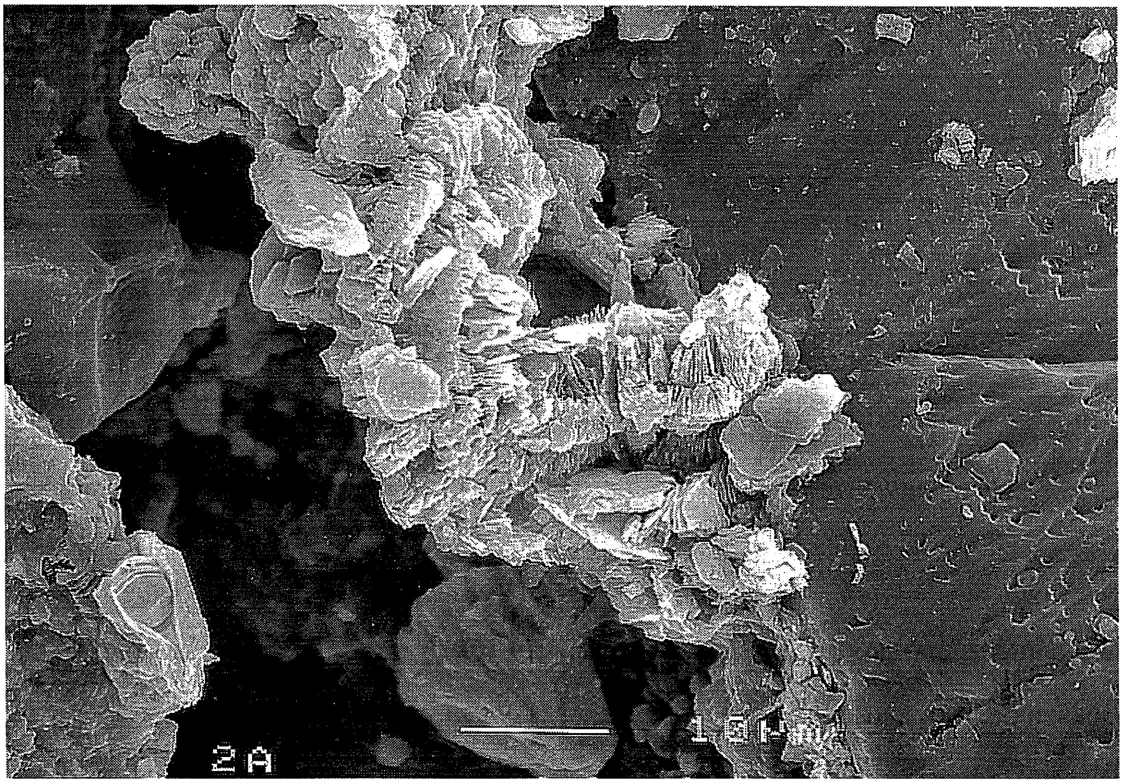

Plate 7: Sample # 2 (1307.50m) SEM photomicrograph showing well developed submicron sized pseudohexagonal kaolinite platelets. The absence of etch pits indicates that no discernible pitting, corrosion or etching has occurred during the cleaning process. Note that the detrital quartz grains exhibit some degree of corrosion. Scale bar = 10 µm.

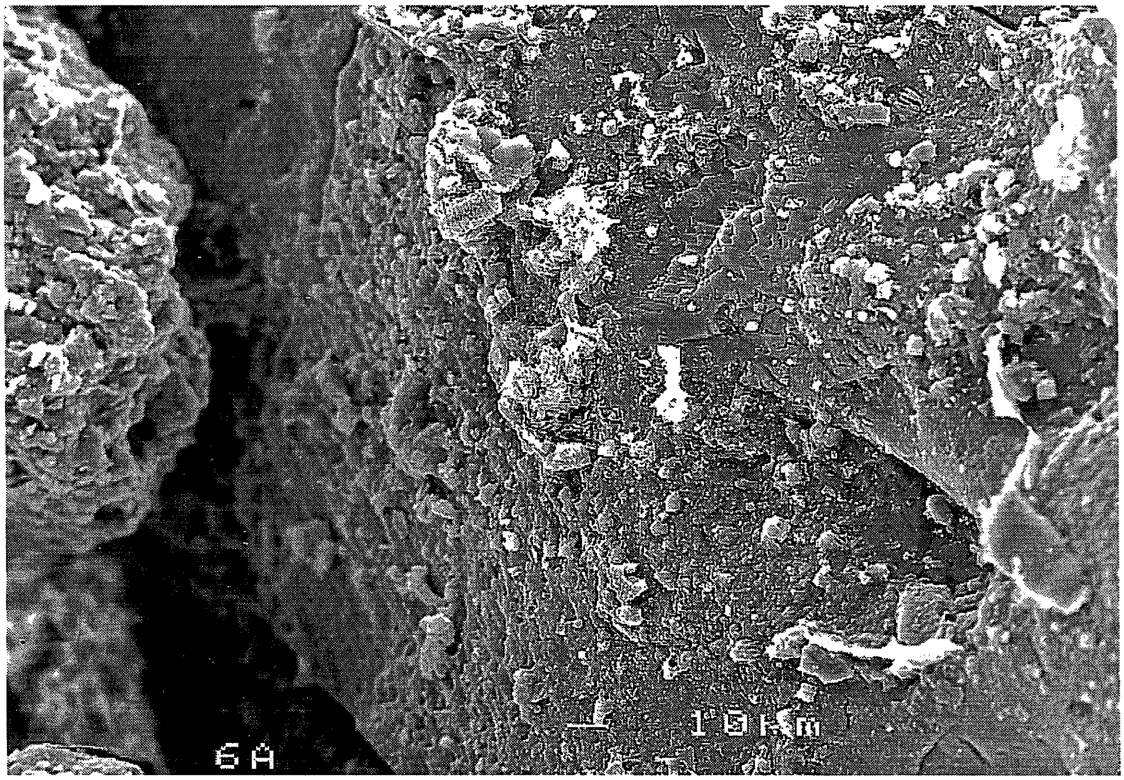

Plate 8: Sample # 6 (1312.40m) SEM photomicrograph showing that the pores are well interconnected in a 3-D network giving good permeability. It seems unlikely for the kaolinite booklets to move to block the pore spaces. Scale bar = 10 µm.

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PE907933

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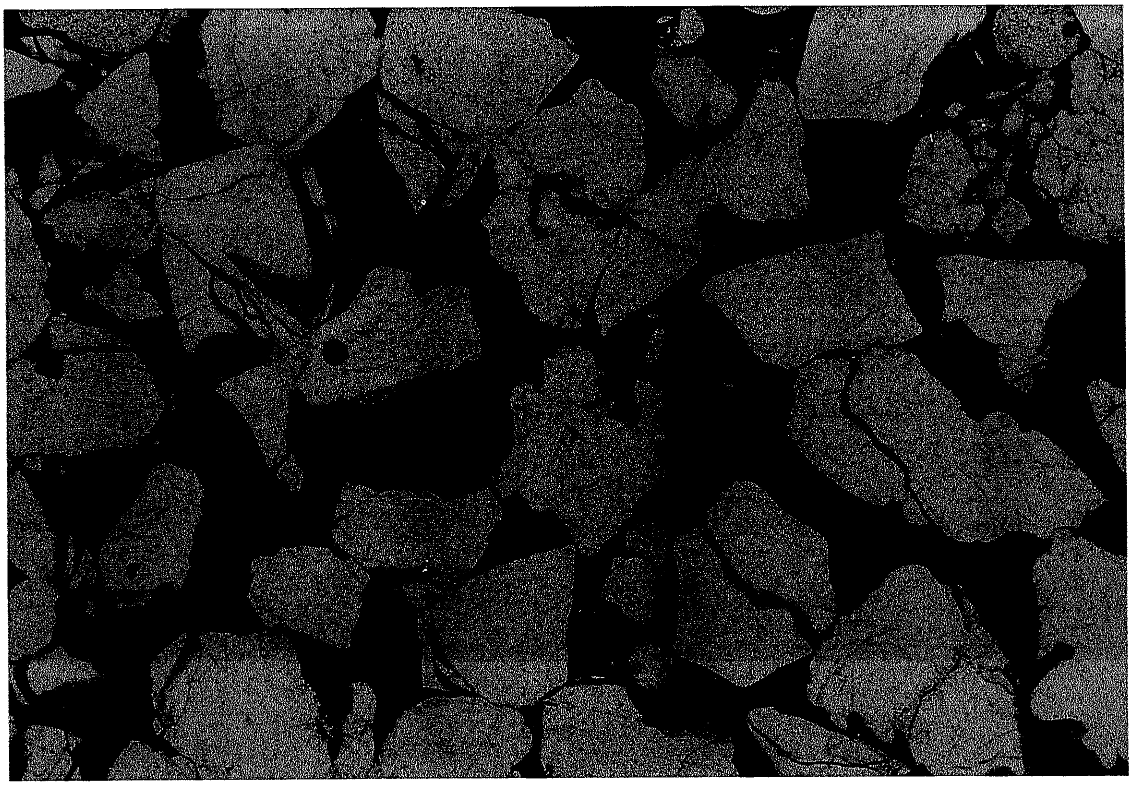


Plate 9: Sample # 2 (1307.50m) Thin section photomicrograph showing considerable amounts of visual porosity are present. Visual porosity dominantly occurs as primary intergranular porosity, elongated and enlarged pores suggesting secondary origin and fracturing. Plane polarised light. Scale bar = 500 μm.

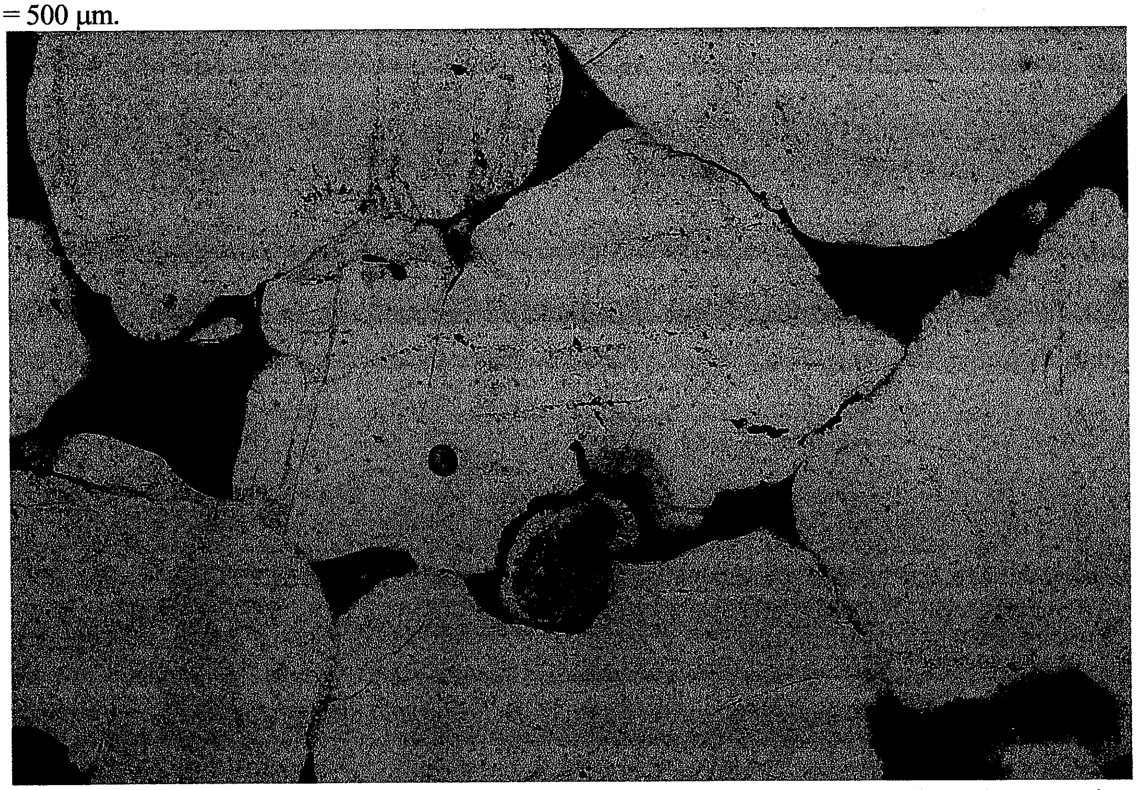


Plate 10: Sample # 2 (1307.50m) Thin section photomicrograph showing the effect of compaction in reducing the primary intergranular porosity. All grains have at leat three contacts with the neighbouring grains, a criterion indicating mechanically consolidated sandstone. Plane polarised light. Scale bar = 200 μm.

PE907934

This is an enclosure indicator page.
The enclosure PE907934 is enclosed within the container PE907925 at this location in this document.

The enclosure PE907934 has the following characteristics:

ITEM_BARCODE =	PE907934
CONTAINER_BARCODE =	PE907925
NAME =	Core Photomicrograph
BASIN =	OTWAY
PERMIT =	PEP 108
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Core Photomicrographs, Plates 11 & 12, (enclosure from Special Core Analysis and Petrological Final Report--attachment to WCR) for Iona-1
REMARKS =	
DATE_CREATED =	22/12/98
DATE_RECEIVED =	24/12/88
W_NO =	W970
WELL_NAME =	Iona-1
CONTRACTOR =	ACS Laboratories Pty Ltd
CLIENT_OP_CO =	Western Underground Gas Storage Pty Ltd

(Inserted by DNRE - Vic Govt Mines Dept)

DEPT. NAT. RES & ENV
PE907934

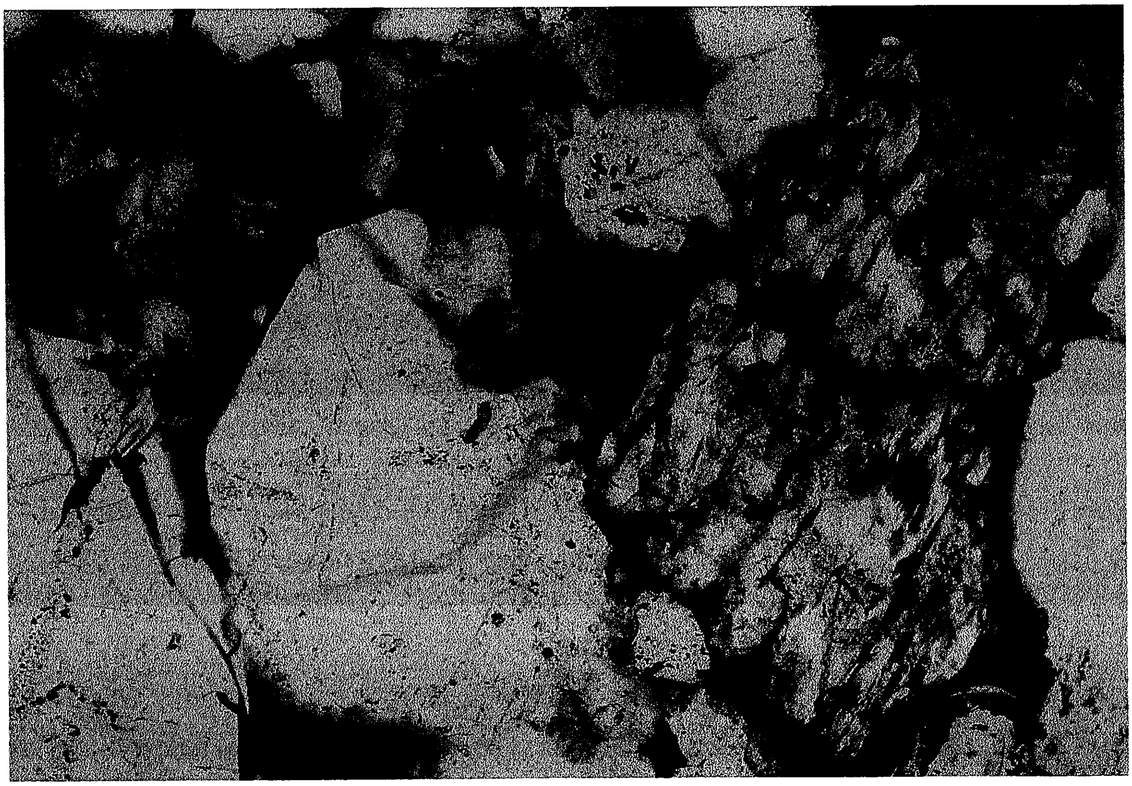


Plate 11: **Sample # 2 (1307.50m)** Thin section photomicrograph showing secondary porosity development which has resulted from partial to complete dissolution of feldspar. It provides good connections between the larger pores. Plane polarised light. Scale bar = 200 μm.

Plate 12: Sample # 2 (1307.50m) Thin section photomicrograph showing traces of infiltrated drilling mud filling some of the pore spaces and coating some of the detrital grains. Plane polarised light. Scale bar = 200 μm.

CHAPTER 6

COMMENTS ON RESULTS

6. COMMENTS ON RESULTS

Sediments Provenance

Subangular to well rounded quartz grains suggest predominance of metamorphic and sedimentary source terrains. The presence of high amounts of monocrystalline quartz and traces of metamorphic and sedimentary rock fragments is interpreted to reflect contribution from a cratonic region.

Environment of Deposition

The well sorting and rounding nature in this fine-grained sandstone indicates deposition in a high energy environment. The moderate grain alignment indicates deposition by traction currents, thus the environment of deposition may have been fluvial, estuarine channel or nearshore shallow marine.

Reservoir Potential

The reservoir quality of the Iona-1 core sample is excellent. The sample contains a considerable amount of both primary and secondary porosity. Visible porosity is 24.4% and interconnected, implying good permeability.

Quality of Core

The quality of the core submitted for analysis was considered poor. This is due to the very limited volume available for sampling (slabbed core that had resin invasion).

Permeability Degradation

The permeability was not affected by the quantity or velocity of the gas flowed through the sample. Permeability to gas declined as a result of the introduction of brine which is normal (relative permeability effects). Significant reduction was experienced at the 40/20 ratio point.

Sand Production

Some material was produced during analysis, the majority of which occurred at the 40/20 ratio point. Analysis of this effluent precipitate yielded a mixture of salt, kaolinite and rust in trace amounts and maximum 25 μm size.

Seal Analysis

From this analysis, two graphs were plotted:

- Saturation (vacuum) versus capillary pressure (page 27) shows the incremental mercury intrusion as a function of increasing capillary pressure. The slope of the plateau is extrapolated to intercept the y-axis at 0 per cent intrusion. This intercept value is interpreted as the breakthrough pressure.

- Pore throat diameter versus intrusion (percentage of total) (page 28) shows the volume of mercury intrusion as a function of pore throat size. A tangent is drawn along the point of first major intrusion. The point where this tangent intersects the x-axis can be defined as the pore throat diameter breakthrough pressure.

Unfortunately the data derived for the sample tested is poor in that the breakthrough pressures are not clearly defined. (In fact, two samples were analysed with similar results).

Mercury injection interpreted breakthrough pressures:	1807 and 1.4 psi
Pore throat size interpreted breakthrough pressures:	7000 psi

The higher mercury injection interpreted breakthrough pressure (1807) could even be greater if the assumed plateau is further 'flattened out'. The value of 1.4 psi is clearly unrealistic. The data has been artefacted by surface imperfections (hairline fractures) which are extremely difficult to avoid in this type of sample. Our interpretation would be 7000 psi. However, the exact breakthrough pressure and equivalent saturation have to be decided by the geoscientist interpreting the data.

APPENDIX I

FLUID PROPERTIES

FLUID PROPERTIES

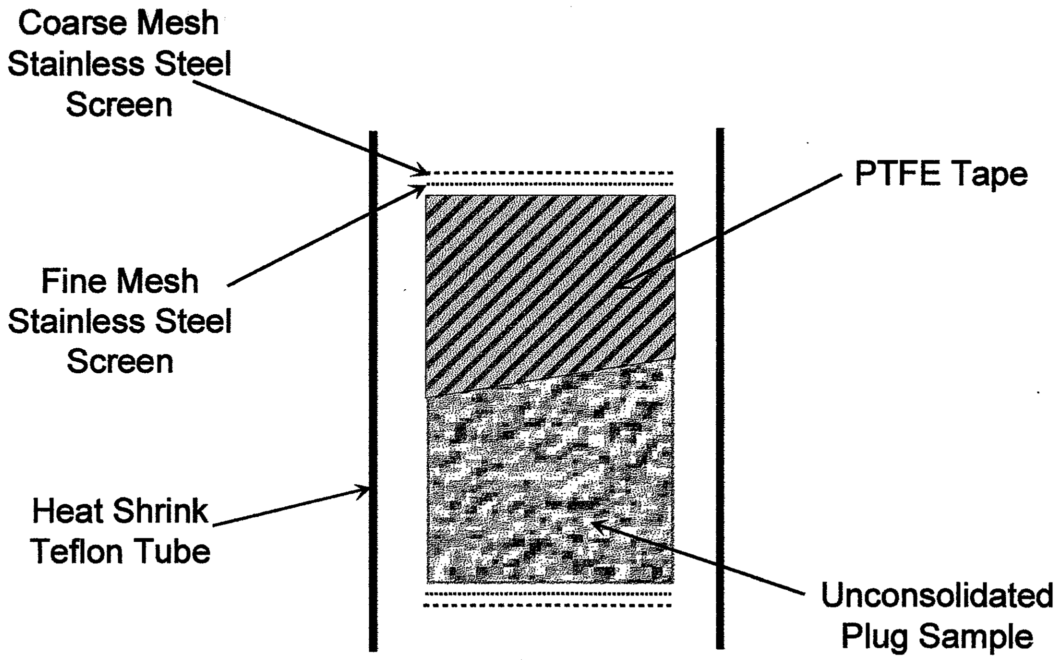
25,000 ppm NaCl Brine

Density @ 20°C = 1.016 g/cm^3

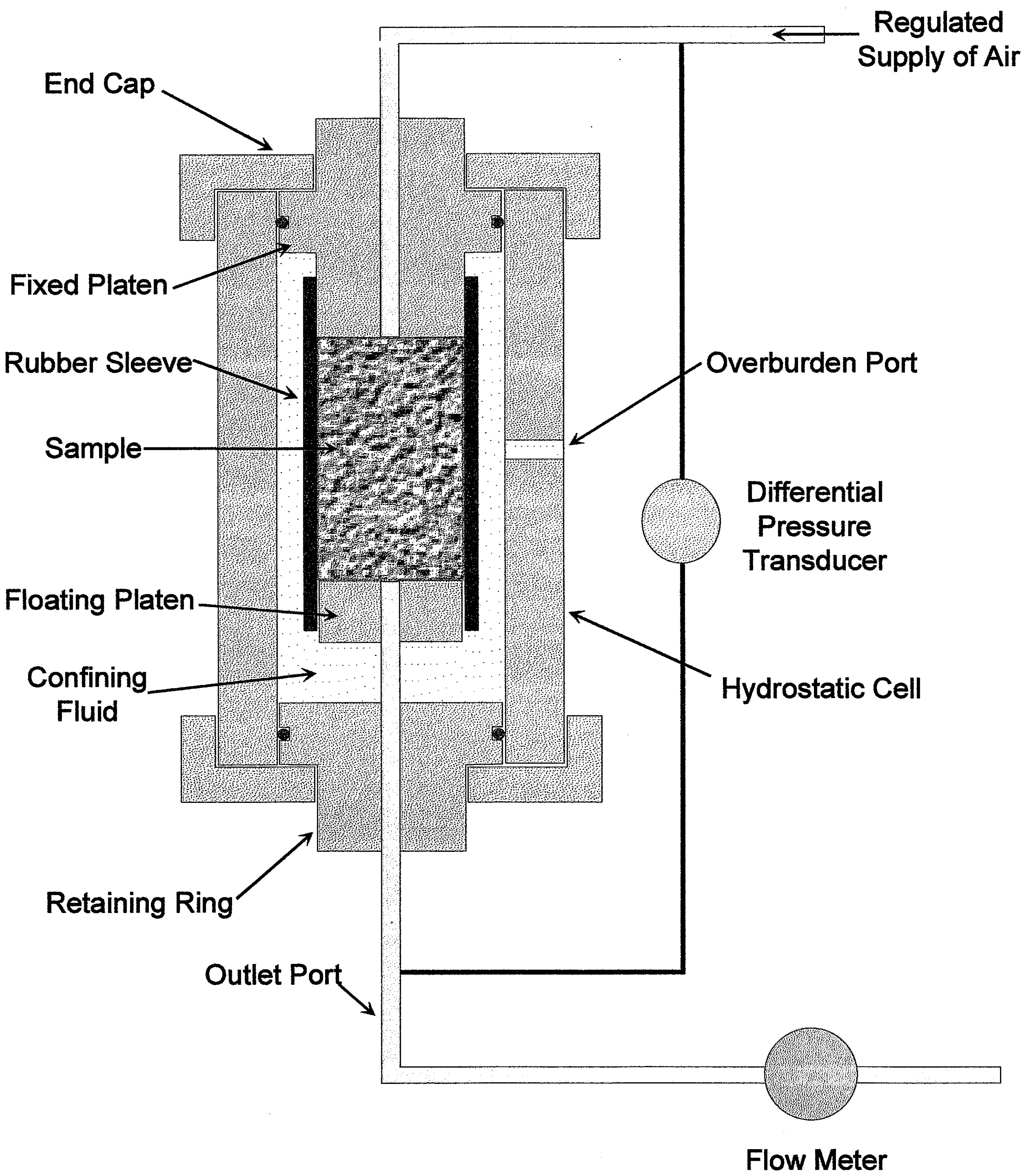
APPENDIX II

EQUIPMENT SCHEMATICS

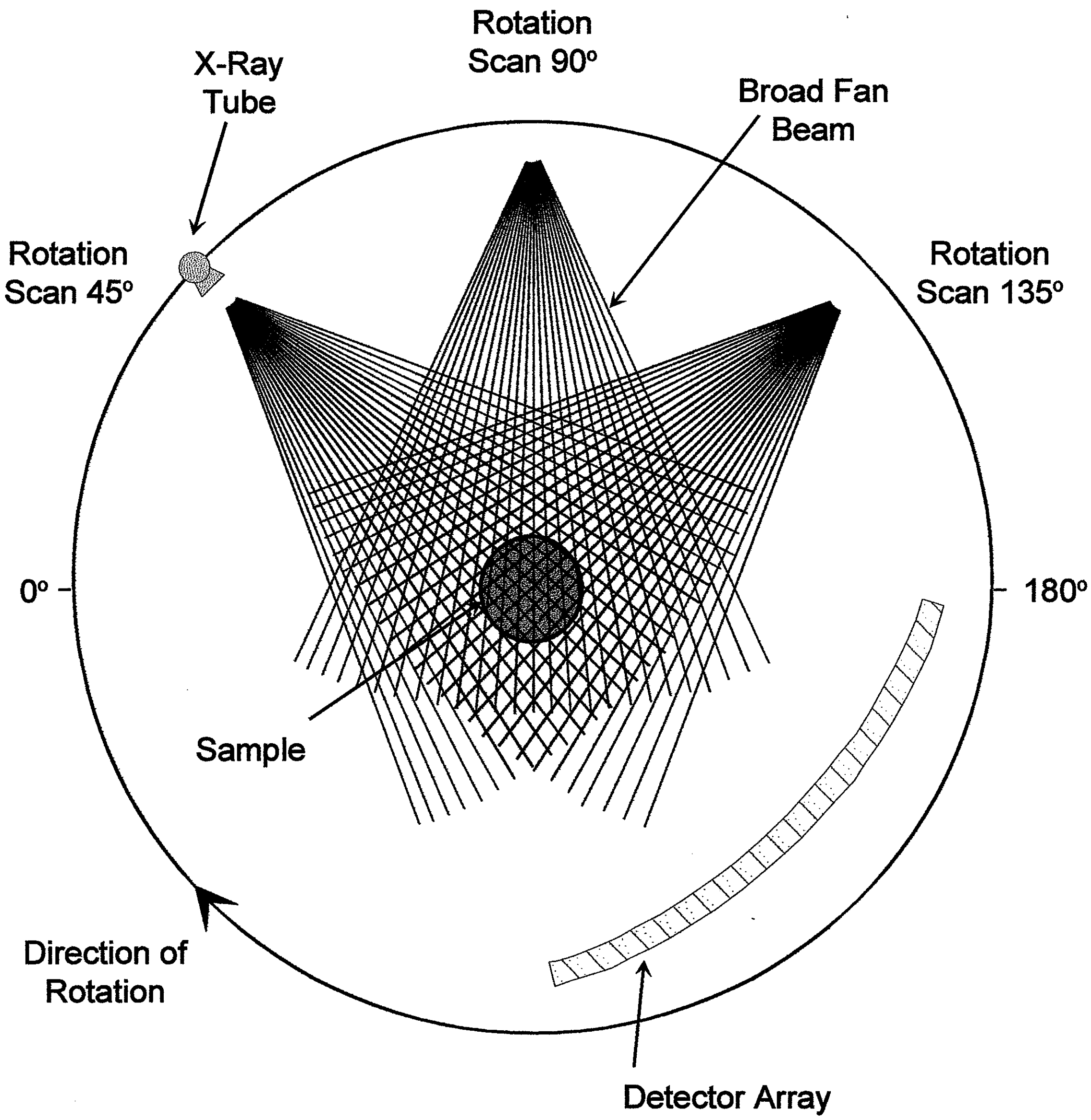
SAMPLE SLEEVE SCHEMATIC (Exploded View)



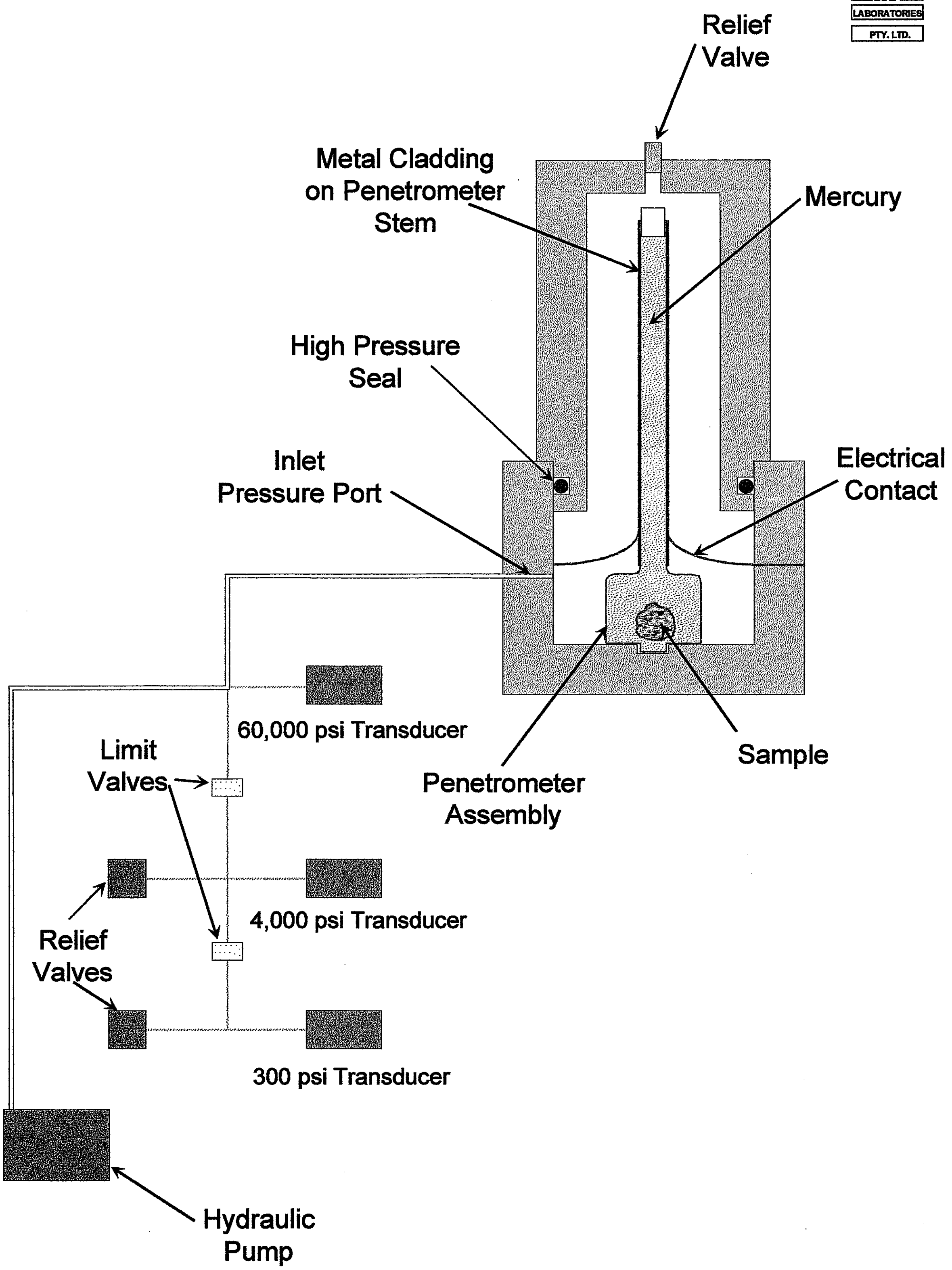
GAS PERMEAMETER SCHEMATIC (Hydrostatic)



CT SCANNER SCHEMATIC



MERCURY INJECTION SCHEMATIC



APPENDIX III

LABORATORY QUALITY CONTROL RECORD

ACS SPECIAL CORE ANALYSES PROJECT
SUMMARY QUALITY CONTROL SHEET:

Client:	**Project No:**	**Well:**
Western Underground Gas Storage Pty Limited	0433-08	Iona-1

Data QC by (name and initials):

Data Set:	Initials:	Checked:	Date:	Comments:
Sample Preparation				
Sample Drilling	JJM		11/11	
Mount Stacks	JJM		11/11	
Solvent Clean	KW.		12/11/98	
Humidity Dry	KW.		16/11/98	
CT Scan	[illegible]		12/11	
Amb & OB Ø Ka	TS		17/11/98	
Saturate	TS		18/11/98	
Analysis				
SngPt Pc to Swr				
Keg @ Swr				
Combine into 1 Stack				
Stack Keg @ Swr	R.V.	R.V.	2/12/98	
Stack Keg @ Swr & ResCon	R.V.	R.V.	3/12/98	
Crit. Thru. to Gas	R.V.		4/12/98	
Crit. Thru. to Gas & Water No1	R.V.		7/12/98	
Crit. Thru. to Gas & Water No2	R.V.		8/12/98	
Crit. Thru. to Gas & Water No3	R.V.		9/12/98	
Crit. Thru. to Gas, Water & Cond.	R.V.	—		Cancelled —
Breakdown & Trim for Petrology	R.V.		14/12/98	
Hg Injection				

APPENDIX IV

FINAL STATUS REPORT

ACS LABORATORIES PTY LTD: SPECIAL CORE ANALYSIS STATUS REPORT

Status Report Number	3

Company:	Attention:	Copy to:	Date:
Western Underground Gas Storage Pty Limited	**Douglas Carsted**	**Andy Whittle**	**18 December 98**
Well/Work:	Fax No.:	Fax No.:	ACS File No.:
Iona-1	**carstedd@ibm.net**	**awhit@emerald.cns.net.au**	**0433-08**

Analysis	No	Date Started	Number Complete	Completion Dates Expected	Completion Dates Actual	Invoice Number	Details	Comments
Sample Preparation								
Plug cutting and trimming	10	12 Nov 98			12 Nov 98			Complete Note 1
Combine two stacks into one	1	20 Nov 98			20 Nov 98			Complete
Keg @ Swr	1	20 Nov 98			20 Nov 98			Complete
Keg @ Swr @ ResCon	1	23 Nov 98			4 Dec 98			Complete Note 2
Analysis								
Critical thru-put to gas @ max drawdow	1	6 Dec 98			7 Dec 98			Complete and Reported
Critical thru-put to gas/brine - Ratio 1	1	8 Dec 98			9 Dec 98			Complete and Reported
Critical thru-put to gas/brine - Ratio 2	1	9 Dec 98			10 Dec 98			Complete and Reported
Critical thru-put to gas/brine - Ratio 3	1	10 Dec 98			11 Dec 98			Complete and Reported
Critical thru-put to G/B/O, single rate	1							Cancelled
Hg injection Seal Analysis	1	18 Nov 98			4 Dec 98			Complete and Reported

Additional Comments/Notes:

1. Samples received on 11/11/98.
2. Information to calculate flow rates received 1/12/98.

PETER CROZIER
Core Properties Manager
Ph: 07 3350 1222
Fax: 07 3359 0666
Email: p.crozier@acslabs.com.au

APPENDIX V

ABBREVIATIONS

ABBREVIATIONS for CORE PROPERTIES

a	Intercept (assumed = 1)
A	Sample Cross Sectional Area (cm^2)
ABPc	Air-Brine Capillary Pressure
Amb	Ambient Conditions (No Overburden Pressure)
B	Equivalent Conductance of Clay Exchange Cations ($mho/m.cm^2.meq^{-1}$)
β	Beta Factor (ft^{-1})
BF	Basic Flood
BHN	Brinell Hardness Number (kg/mm^2)
BP	Barometric Pressure (atm)
CEC	Cation Exchange Capacity (meq/100g dry sample)
Cent	Centrifuge
Co	Conductivity of Fully Brine Saturated Sample (mho/m)
cP	Centipoise
Cw	Conductivity of Brine (mho/m)
Dr	Drainage (i.e. draining of the wetting fluid - usually brine)
Φ	Porosity
FF	Formation Factor
*FF**	Shaly Sand Equivalent Formation Factor
g	grams
HeInj	Helium Injection
HgInj	Mercury Injection Capillary Pressure
Imb	Imbibition (i.e. imbibition of the wetting fluid - usually brine)
K	Permeability (mD)
Ka	Air Permeability (mD)
Keg	Effective Permeability to Gas (mD)
Keo	Effective Permeability to Oil (mD)
Kew	Effective Permeability to Water (mD)
Kg	Gas Permeability (mD)
KgKo	Gas-Oil Relative Permeability

ABBREVIATIONS for CORE PROPERTIES

KgKw	Gas-Water Relative Permeability
Klink or Kl	Klinkenberg Permeability (mD)
Ko	Oil Permeability (mD)
Krg	Relative Gas Permeability
Kro	Relative Oil Permeability
Krw	Relative Water Permeability
Kw	Brine Permeability (mD)
KwKo	Oil-Water Relative Permeability
L	Sample Length (cm)
m	Cementation Factor
*m**	Shaly Sand Equivalent Cementation Factor
mD	milliDarcy's
n	Saturation Exponent
*n**	Shaly Sand Equivalent Saturation Exponent
OB	Overburden Pressure (psig)
OBPc	Oil-Brine Capillary Pressure
P	Pressure (psi)
Pc	Capillary Pressure (psig)
PP	Porous Plate
PvComp	Pore Volume Compressibility
PVR	Pore Volume Reduction (cm^3)
ρ	Density (g/cm^3)
q	Flow Rate (cm^3/s)
θ	Contact Angle (degrees)
Qv	Volume Concentration of Clay Exchange Cations (meq/cm^3)
r	Radius (cm)
Rc	Sample Resistance (ohm)
RCA	Routine Core Analysis

ABBREVIATIONS for CORE PROPERTIES

ResCon	Reservoir Conditions
RI	Resistivity Index
RICP	Resistivity Index & Capillary Pressure
Ro	Resistivity of Fully Brine Saturated Sample (ohm.m)
Rt	Resistivity of Partially Saturated Sample (ohm.m)
Rw	Resistivity of Brine (ohm.m)
S	Saturation
s	Seconds
SCA	Special Core Analysis
Sg	Gas Saturation
Sgr	Residual Gas Saturation
SngPt	Single Point
So	Oil Saturation
Sor	Irreducible Oil Saturation (or Residual Oil Saturation)
SS	Steady State
Sw	Brine Saturation
Swi	Initial Water Saturation
Swir	Irreducible Water Saturation
Swr	Residual Water Saturation
T	Temperature (°C)
USS	Unsteady State
μ	Viscosity (cP)
Vb	Bulk Volume (cm^3)
Vg	Grain Volume (cm^3)
Vp	Pore Volume (cm^3)
ω	Angular Velocity (rad/s)
Wett	Wettability
Wt	Weight (g)